

**An Exploration of Job Strain with Australian Workers' BMI:
Is There an Association?**

Brie Sage

**A thesis submitted for the degree of Doctor of Philosophy of
The Australian National University**

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Declaration and Statement of Candidate's Contribution to the Research

I, Brie Sage, declare that this thesis is the product of my own work carried out under the primary supervision of Doctor Liana Leach. The work presented in this thesis is original, to the best of my knowledge, except as acknowledged in text.

Longitudinal data from waves one-to-four of the Personality and Total health (PATH) Through Life study was used to conduct this research. The PATH study was initially designed and conducted at the Centre for Mental Health Research (CMHR) at The Australian National University, and the study is currently jointly hosted by the Australian National University and the University of New South Wales. I independently analysed all data and drafted all the chapters for this thesis. The analyses and chapters were then reviewed by my supervisory panel. Dr Liana Leach and Dr Richard Burns provided feedback on all analyses and chapters. Professor Peter Butterworth provided feedback on all analyses and sections throughout Chapters 1, 2, 3, 4 and 5. I affirm that this thesis is in accordance with The Australian National University Guidelines for higher degree research.

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22 August 2022

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Abstract

Work stress is prevalent within Australia and globally, with the potential to adversely affect individuals, organisations, and economies. Similarly, the increase in population body mass index (BMI) is an ongoing trend internationally that is associated with negative outcomes for individuals' and populations' health, as well as economic loss for individuals, organisations, and society. The simultaneous rise in both work stress and BMI, combined with additional evidence to hypothesise a connection, suggests that there may be a causal relationship between these public health issues. Job strain is a widely used and validated measure of work stress (Karasek, 1979; Karasek & Theorell, 1990). However, existing research investigating an association between job strain and BMI is mixed, and there is a lack of research particularly within Australia. The main aim of this thesis is to explore evidence for an association between job strain and BMI. Data were used from the Personality and Total Health (PATH) Through Life survey, which is a community-based longitudinal survey (with four waves of data) sampling three age cohorts (20s, 40s, 60s) from the Canberra region (Australian Capital Territory, Australia).

Four investigations, building upon each other, were conducted. The first analyses chapter used cross-sectional data to search for evidence of an association between job strain and BMI. Logistic regressions were used to examine whether job strain was associated with overweight or obesity (1,947 males and 1,981 females from the 20s and 40s cohorts sampled at wave 2). Linear regressions modelled BMI continuously as a function of job strain using the same sample. No evidence was found of an association between job strain and overweight, obesity, or continuous BMI. However, the possibility remained that job strain may be associated with BMI over time.

The second analyses chapter investigated the possibility that job strain may be associated with BMI over time. Four waves of data measured from the 40s cohort (1,130

males and 1,141 females) across 12 years were used to explore this possibility in four sets of multilevel models (MLMs). No evidence was found that job strain was associated with BMI over time.

The third analyses chapter considered whether individuals' higher or lower than average BMI at baseline moderated the effect of job strain on BMI over time. To do this, the four MLMs used in the prior chapter were re-employed with an interaction term for baseline BMI included. Baseline BMI was modelled continuously and categorically in interaction with job strain (in separate analyses), and job strain was also tested as a predictor of BMI over time in analyses stratified by the baseline BMI category. While there were some inconsistent results between analyses with BMI modelled differently, particularly for females, there was minimal evidence that a relationship between job strain and BMI was dependent upon BMI at baseline.

The fourth analyses chapter examined whether counts of job strain accumulate over time to affect BMI at follow-up, and whether this may be dependent upon baseline BMI. Participants from the 40s cohort with data on job strain at every wave and BMI at baseline and follow-up were analysed (525 males and 464 females). Linear regression was used to examine whether BMI at follow-up was associated with one, two, or three/four (combined) counts of job strain compared to individuals who did not experience job strain (zero counts). There was no evidence of a pattern of increasing association between more counts of job strain and BMI outcomes, both in direct analyses and in those dependent upon BMI at baseline.

Overall, this thesis finds no evidence that job strain is meaningfully associated with BMI in this Australian sample. However, there is a need to replicate these findings with job strain and explore broader measures of work stress in connection with BMI in further large, Australian population-based longitudinal samples.

Peer-Reviewed Conference Presentation

Sage, B. (2019, November 6-9). *Investigating the association of job strain, demands and control with BMI over time: Results from the PATH Through Life study*. Research presented at the Work, Stress and Health Conference 2019, Philadelphia, US.

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Overview of Thesis's Structure and Content

Outline of Thesis

Work represents a substantive presence in the lives of many individuals, and the working population is integral in shaping societal systems. Maintaining the health of workers is important for the interests of individuals, communities, organisations, industries, and governments. The workplace environment plays an important role in maintaining the health of workers and is influenced by the nature of the work required. The nature of work has changed rapidly over the past few decades, introducing new risks (Siegrist, 2006; Wooden, 2021). Evidence shows that work has become more insecure/casual, that people are working longer hours in some jobs, and that while job flexibility has increased for some workers, it has come with the expectation that they are more available (outside the usual 9 a.m. to 5 p.m. hours) (Matthews et al., 2005; Messenger, 2018; National Research Council, 1999; Wooden, 2021). While workplace health and safety has continued to evolve to protect workers' health, stress from work is a prominent public health concern (De Sio et al., 2017; EU-OSHA, 2000; LaMontagne et al., 2010).

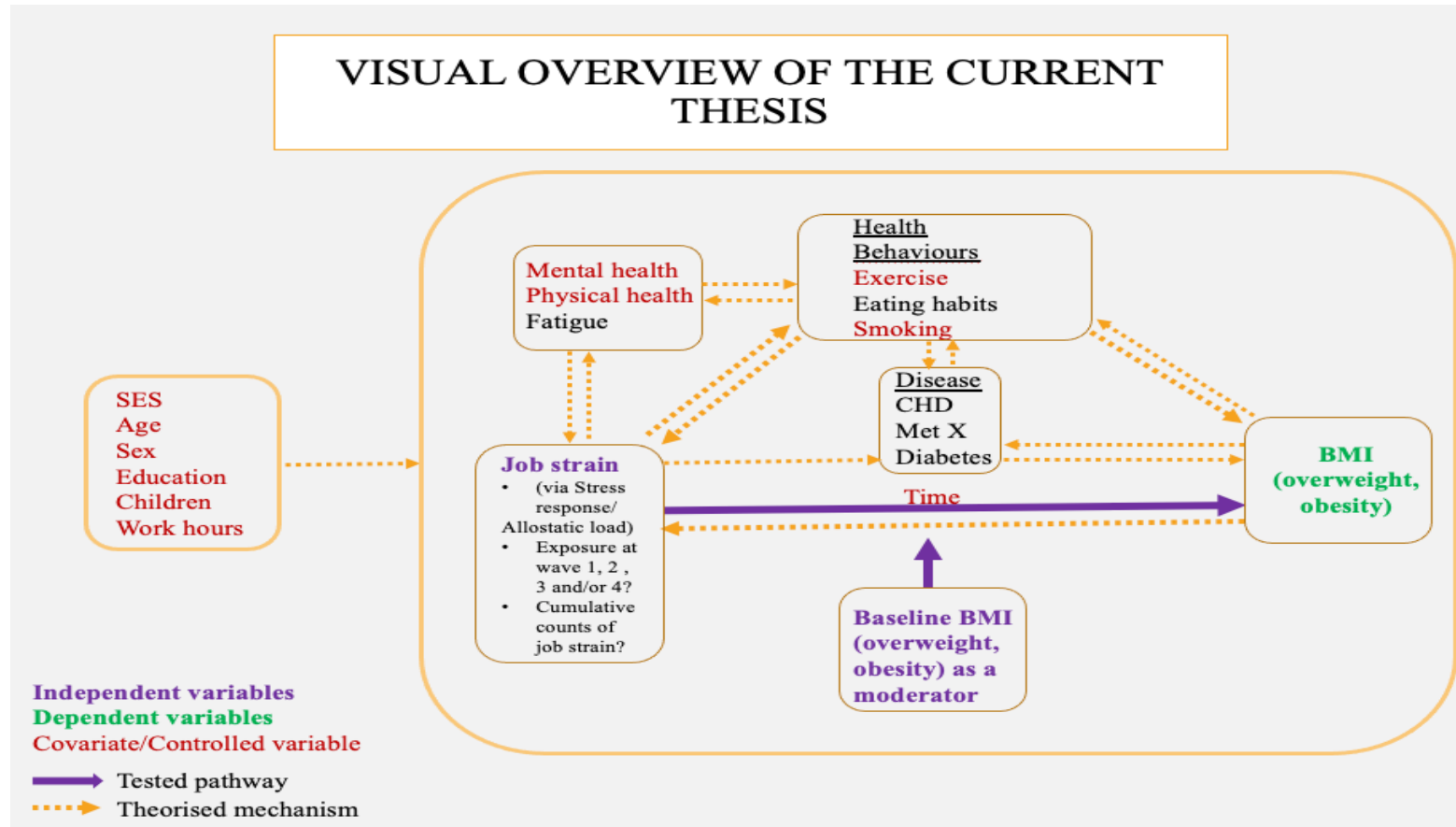
Two central societal (and health) trends that form the backdrop for the current thesis are the simultaneous increases in both work stress and BMI at the population level (AIHW, 2003, 2021a, 2021b; Safe Work Australia, 2019; Black Dog Institute, 2021). This raises the central question addressed in this thesis: Is stress at work associated with increases in BMI? Stress, from a range of different sources, has been found to be associated with poorer health outcomes, including obesity and high levels (and in some studies low levels) of BMI (Geiker et al., 2018; Grami, 2017; Razzoli et al., 2016; van der Valk et al., 2018). This robust evidence base for an association between general stress and BMI, and the co-occurring increase of both in the population, forms the basis for reasoning that work stress specifically may be associated with BMI. The central indicator of work stress investigated in this thesis is

job strain—the combination of high job demands and low job control (Karasek, 1979). Job strain, one of the most widely used measures of work stress, represents an increased risk of harm arising from experiencing high job demands and little control over how to manage and meet the demands.

Figure 1.0 is a visual representation of the important variables in this thesis and their theorised relationships, including a methodological blueprint for the relationships examined here. While the specific research questions and analyses included in this thesis focus on the association between job strain and BMI, the figure includes other important conceptual pathways and mechanisms underlying the rationale to expect work stress to be associated with BMI. The figure proposes that job strain may be associated with BMI both indirectly—through health behaviours—and directly—through the biological effects resulting from the stress response of the human body. Important contextual factors are also presented (e.g., socioeconomic status, gender, and other covariates) (Clarke et al., 2009; Gebremariam et al., 2018; Hayes et al., 2019; Sund et al., 2010). While the literature surrounding these pathways is summarised and discussed to provide an important conceptual context in the introduction of this thesis, only the relationship between job strain and BMI is formally tested and analysed (along with the possibility that this association is moderated by baseline BMI, as explained in more detail below). Further, while it is likely that job strain and BMI may be related bidirectionally, the focus of this thesis is to examine the unidirectional relationship between job strain and BMI, where the exposure or stressor is job strain and the outcome is BMI.

Figure 1.0

A Visual Overview of the Current Thesis



Note. The solid arrows indicate the associations examined/analysed in the current thesis, while the dotted lines indicate the pathways between job strain and BMI for which evidence exists.

To date, a small body of research using community-based and general populations has attempted to determine whether job strain is associated with BMI, overweight and obesity. The findings from these studies are mixed: some indicate no association, while those that find evidence for an association are inconsistent and, at times, conflicting (Brunner et al., 2007; Fujishiro et al., 2015; Kivimäki et al., 2015; Klingberg et al., 2019; Solovieva et al., 2013; Wardle et al., 2011). While the state of the mixed literature casts doubts on whether an association exists at all between work stress and BMI, some longitudinal studies and those with higher methodological quality support a small association (Brunner et al., 2007; Nyberg et al., 2012; Solovieva et al., 2013; Wardle et al., 2011). However, even among these more robust studies, there are inconsistent findings, prompting the need for further investigation. Inconsistencies in study samples (e.g., sex stratification, sample sizes), variable measurement, and analysis techniques require closer examination to better understand the different findings in the literature.

Overall, the question of whether there is an association between job strain and BMI remains unanswered. The broad aim of this thesis is to explore this question using data from a longitudinal community-based cohort study of workers in mid-life (Chapter 2 provides an overview of the data). Table 1.0 outlines the structure of the thesis. The introduction summarises and discusses the literature surrounding the important conceptual context regarding the potential direct and indirect pathways between job strain and BMI. Subsequently, each of the analyses chapters begins with a critical review of the relevant literature directly addressing job strain and BMI. A variety of analyses are applied (e.g., cross-sectional [Chapter 3], longitudinal mixed models [Chapter 4]) to investigate the question of whether there is an association between job strain and BMI. The examination of job strain and BMI longitudinally raises an important consideration- that is, whether an association of job strain with BMI may be moderated by their initial BMI position in the BMI

distribution at the beginning of the study (baseline): that is, whether an association of job strain with BMI may differ dependent upon individuals' baseline BMI. Thus, a thorough examination of the moderating role that baseline BMI may have in an association between job strain and BMI is undertaken (Chapter 5). Finally, building on the critical analysis and findings in the cross-sectional, longitudinal and baseline BMI chapters, the final analysis chapter (Chapter 6) examines whether reporting job strain more than once, that is, accumulated job strain over time, is associated with future BMI.

Table 1.0

Overview of the Present Thesis's Structure and Content

	Chapter Title
Chapter 1	Introduction and Aims of Thesis: Direct and indirect basis for a relationship between job strain and BMI
Chapter 2	Methodology
Chapter 3	Cross-Sectional Investigation of Job Strain, Overweight & Obesity, and BMI: Literature review, analyses, and discussion
Chapter 4	Is There an Association Between Job Strain and BMI Outcomes Over Time? Investigating Longitudinal Associations: Literature review, analyses, and discussion
Chapter 5	Does Baseline BMI Affect the Relationship Between Job Strain and BMI Over Time? Literature review, analyses, and discussion
Chapter 6	Does Job Strain Accumulate to be Associated with BMI 12 Years Later? Literature review, analyses, and discussion
Chapter 7	General Discussion and Conclusion

Note. Bold type indicates analyses chapters.

The four analyses chapters build on each other to present a deep exploration of the overarching aim—namely, to investigate whether there is evidence of an association between job strain and BMI. The findings from each chapter are largely consistent in showing no evidence that job strain is associated with BMI. The cross-sectional analyses examining job strain in association with continuous and categorical BMI outcomes (in parallel analyses) finds no evidence of a relationship (Chapter 3). This null finding is reflected in the results of the four longitudinal multilevel models examining job strain in association with BMI over time (Chapter 4). The examination of whether baseline BMI moderates the relationship between job strain and BMI over time (Chapter 5) returns some inconsistencies for females in analyses with BMI modelled continuously compared to when BMI is modelled categorically. However, further stratification of analyses by baseline BMI category does not support the hypothesis that an association between job strain and BMI may be moderated differentially according to baseline BMI. Concluding the comprehensive program of research, further investigations show no evidence that job strain accumulated over time is connected to future BMI (Chapter 6). The null findings across Chapters 3-6 are largely similar for males and females.

The final chapter (Chapter 7) summarises the findings of the four analyses chapters and concludes that no evidence of an association between job strain with BMI was found in this comprehensive exploration. While some findings in the analyses in Chapter 5 were inconsistent and further research is recommended, the sum of the evidence from each investigation suggests that experiencing job strain is not connected to individuals' BMI. Despite this, this epidemiological investigation of the association between job strain and BMI contributes important insights and knowledge to help direct future research. The study of whether stress in the workplace has any positive or negative associations with BMI will guide efforts to identify targets to reduce the concerning trend of BMI growth at the population

level. In this final chapter, the findings and conclusion are discussed in the context of existing research, highlighting the strengths and limitations of the current thesis. It is discussed that it would be premature to dismiss work stress as a modifiable target in addressing the population increase in BMI.

Chapter 1: Introduction and Aims of Thesis

1.1 Chapter Summary

This thesis investigates whether there is an association between job strain and body mass index (BMI). This introductory chapter lays the foundation for the investigation of these main concepts by drawing on research and discussions outlining the importance, background, and overlap of each concept. The chapter discusses reasons to theorise the existence of an association between job strain and BMI, while empirical research discussing the evidence of the association is discussed in later chapters (in connection with the analyses undertaken).

This chapter begins with a discussion of the importance of the workplace and workplace psychosocial characteristic, with an emphasis on the increasing negative burden of job strain within the Australian context. While parts of this thesis are discussed and conceptualised within the broader concept of ‘work stress’, the focus of this thesis is on job strain explicitly, because job strain is widely recognised as a key psychosocial job stressor reliably associated with a variety of health outcomes (Fransson, Nyberg, et al., 2015; Fransson, Stadin, et al., 2015; Heikkilä et al., 2013; Kuper & Marmot, 2003; Theorell, 2014). Accordingly, a discussion of job strain and the theory from which it arises—the job demands and control (JDC) model (Karasek, 1979; Karasek et al., 1998)—is presented in this chapter. The direct (biological) and indirect (behavioural) mechanisms thought to underlie the relationship between experiencing stress and negative health outcomes are also outlined. Mechanisms specifically related to the shared overlap between job strain and BMI are the focus, including direct biological (i.e., allostatic load, metabolic syndrome, type 2 diabetes) and indirect energy balance–related behaviours (i.e., physical activity, eating patterns).

Following a conceptual overview of job strain and the possible pathways between job strain and BMI, overweight and obesity are discussed as public health priorities. Throughout, individual BMI increase over time is highlighted as the underlying process leading to

overweight and obesity, and the value of examining both changes in the population BMI distribution and the prevalence of overweight and obesity BMI categories is emphasised. Next, the broader variables that create other overlapping pathways between job strain and BMI—specifically fatigue and mental and physical health—are explored. Throughout, the possibility of sex differences in the association between job strain and BMI is highlighted. A summary of these potential differences is provided at the end of the chapter, evidencing the benefits from analysing males and females separately throughout this thesis.

Overall, this introductory chapter lays the foundation for theorising an association between job strain and BMI, and the possible pathways through which this may exist. In summarising the chapter, it is noted that laying this foundation is an important first step before discussing the existing empirical research evidence directly testing job strain and BMI, which is presented in each of the subsequent analyses chapters. Finally, the research questions and aims are presented as an overview of the following investigative/analyses chapters, setting the program of research that has been undertaken.

1.2 General Overview of Work Stress: A Psychosocial Characteristic of Work

1.2.1 Work and Health

‘Work’ as a standalone term is defined as ‘mental or physical efforts to achieve a purpose or result’ (Oxford Dictionary, 2013). This is a broad and general definition that encompasses unpaid work; however, the current thesis is concerned with paid work employment. Work represents a substantive presence in the lives of many individuals, with more than half (57%) of the world’s working-age population estimated to be in paid employment (ILO, 2020). Time spent at work or working occupies a significant portion of life for most workers, especially when viewed across the lifespan. It is not a surprise, then, that theory and research show that work has direct and indirect links to the health of workers

(Bliese et al., 2017; Chandola et al., 2010; Jick & Payne, 1999; Karasek & Theorell, 1990; Nixon et al., 2011).

Work can affect the physical, psychological, and social health and wellbeing of workers. How work affects health appears to be influenced by a range of variables occurring at various levels. For example, the worker, direct work environment, organisational structure and culture, and government policy and regulation relating to working standards each offer pathways through which work can influence health, although they occur at varying distances from the individual workers (Theorell, 2014; Wahrendorf & Siegrist, 2014). From this perspective, there are individual workers and their health outcomes that occur within, and are connected to, varying ‘micro-, meso- and macro- socio-political and economic environments’ (Masood & Reidpath, 2017, p. 2). Multilevel theories that exist within social epidemiology are excellent frameworks for understanding complex interrelationships such as that between work and health. For example, ecosocial theory (Krieger, 1994) describes the intertwined nature of every level and experience of life, from micro to macro (Masood & Reidpath, 2017). Applied here, the work environment and the health of the working population are integral in shaping the societal systems we exist within. In turn, these societal systems shape the work environments and characteristics, including health, of the working population.

The Organisation for Economic Co-operation and Development (OECD, n.d., Health and Work) states that ‘health is a critical labour market determinant’, reflecting that individuals who are healthy are more likely to be employed and to be productive in their employment. Therefore, maintaining the health of the working population is imperative for sustainable economic growth and development, which is an important factor in providing sufficient resources for health systems (OECD, n.d.). Acknowledging the reciprocal relationships between work and health, the health of workers (and how work affects health) has increasingly been the focus of attention and is broadly covered under the term

‘occupational health and safety’ (Bean, 2017; Safe Work Australia, 2019). Occupational health and safety has traditionally focused on physical, environmental, and chemical workplace risks, likely because these are easier to observe, define, and measure (Clougherty et al., 2010; Marmot et al., 2006; Sauter et al., 1999).

By comparison, it is only more recently that psychological and social risks in the workplace have been considered for their effect on workers’ safety, health, and wellbeing (Fingret, 2000). These psychosocial risks have been investigated across many disciplines and are broadly covered under the term ‘occupational health psychology’ (Bean, 2017; Sauter et al., 1999). In epidemiology, this issue has been reflected in the research of social epidemiologists, who blend the study of psychosocial work characteristics with applications for broad health outcomes across and within populations to understand how work can influence health, and to provide insights into the promotion and maintenance of optimal health for workers (Bean, 2017; Karasek & Theorell, 1990; Winefield, 2013).

1.2.2 Complexities of Researching ‘Work’

There is enormous variation in the application and context of work. ‘Work’ differs by contract type (i.e., full-time v. casual), schedule (shift work v. set hours), field (i.e., white-collar jobs v. blue-collar jobs), industry and occupation within different fields (i.e., mining v. construction), different areas within companies (i.e., human resources v. accounting), and broadly differing employee roles (i.e., managerial/supervisory v. worker), etc. The structure of the Australian and New Zealand Standard Classification of Occupations (ANZSCO) is testimony to the complexity of attempting to organise occupations within defined groups. The ANZSCO has eight major groups, which in turn have 43 sub-major groups, which contains 97 sub-minor groups, which are grouped into 358 unit groups, within which 1,023 occupations are listed (ABS, 2013a). However, despite the complexity of the ANZSCO hierarchy, further qualifying aspects of the occupations that are listed, such as contract types

and working schedules, are not described within this system. The breadth and depth of the concept of work highlight a difficulty facing researchers who are interested in studying the field (Warren & Kuo, 2003), especially in attempting to maintain the generalisability of results (Clougherty et al., 2010). One method to both simplify and make meaningful distinctions between job types, and particularly job quality, and to facilitate the cross-comparison of research, is to differentiate between physical and psychosocial work-related variables (EU-OSHA, 2000).

Physical aspects of work are both easier to define at the conceptual level and easier to operationalise and measure than psychosocial characteristics. This is because psychosocial characteristics are not easily directly observed and are thus largely inferred from self-report data. Psychosocial characteristics, as the compound term implies, refer to both social and psychological aspects of the workplace that affect individuals at either the psychological, emotional, physical, or behavioural level (EU-OSHA, 2000). Most research surrounding psychosocial aspects of work has centred on potential negative impacts, which are commonly termed ‘workplace psychosocial risk factors’ (Marmot et al., 2006). These can be defined as social or psychological aspects of work that have the potential to cause psychological, social, or physical harm (EU-OSHA, 2000).

1.2.3 The Prevalence and Impact of Work Stress

1.2.3.1 Economic Impacts of Work Stress

Work stress is one of the most salient psychosocial aspects of work that has been investigated in depth, particularly for its impact on health and wellbeing. Work-related stress has been an increasingly popular topic over the past 30 years, largely because of the growing awareness that work-related stress is a major expense to both organisations and national economies (Brijnath et al., 2014; Medibank Private, 2013; Safe Work Australia, 2019; Smith, 2010). While work stress is not a recognised disease or condition and is regarded as a lived

experience, the detrimental impacts on health and wellbeing from experiencing work stress are considerable. Work stress is associated with lost productivity, absenteeism, presenteeism, and high employee turnover (Dollard et al., 2000; McTernan et al., 2013; Sang, 2014; Söderberg et al., 2014; Suominen et al., 2007). The cost of treatments and interventions for physical and psychosocial disease associated with work stress leads to rising costs for employers and, ultimately, economies. For example, in 2020, the cost of work-related poor mental health in Australia (including work stress) was estimated at \$39 billion as a result of lost participation and productivity (Black Dog Institute, 2021; Productivity Commission, 2020). Declines in mental health in turn decrease work productivity, which is commonly indexed via absenteeism (absence from work due to being unwell) and presenteeism (being present at work while unwell). Whilst presenteeism is often less studied than absenteeism, the cost of lost productivity due to presenteeism is often equal to that of absenteeism, which is borne by employers (Cocker, Sanders, & LaMontagne, 2017).

In accordance with the increasing prevalence and impact of work stress, leading occupational health and safety academics have identified psychosocial workplace risks as one of the top three national priorities for further research in Australia (Smith, 2010). Evidence suggests some congruence between job strain (a specific form of work stress, discussed further below) and ‘mental stress’ work compensation claims (Keegel et al., 2009). While work compensation claims as an indicator of work stress are predicted to largely underrepresent the prevalence and impact of work stress, workers compensation statistics in Australia are used as primary sources to direct and inform work stress policy.

Safe Work Australia, an agency established to raise awareness of work healthy and safety, estimates that the costs and trends in workers compensation claims are increasing. In 2006, Safe Work Australia estimated that work-related stress would cost an average \$200 million per year in workers compensation claims (Australian Safety and Compensation

Council, 2006). However, in its 2019 report, Safe Work Australia noted that these costs had increased by 209% over the past 18 years, and that work stress–related claims involved the highest median compensation amounts for all diseases in recent years. The median cost of work stress was almost three times greater than the median cost of other claims. The increasing trend in work stress is despite a declining number of serious work-related claims overall. In fact, as physical injury claims decreased between 2000 and 2018, work stress–related claims increased by 38% over the same period and represented 66% of all disease (rather than physical injury) claims.

While work stress only accounts for around 8% of all compensation claims, it has the highest median cost per claim. This is because work stress, apart from bone fractures, is associated with the longest time off work, even above common physical injuries such as strains and sprains (ABS, 2011). While the median time lost for all claims is 6.2 weeks, the median time lost because of work stress claims is 21 weeks. This represents an increase of eight weeks above the median time lost in 2000, although work stress claims had the highest median time lost for every year of data collection after 2000 (from 2000 to 2018) (Safe Work Australia, 2019). The data from Safe Work Australia also show that sex may be an important moderating factor in experiencing work stress, particularly for females. Work mental stress had the greatest difference in claims between sexes, with work mental stress accounting for 5% of the total claims made by males and 13% of the total claims made by females. The disparity by sex in work mental stress claims is accentuated by the context that all other claim types (not mental stress) involved similar proportions of claims between sexes.

While these statistics are evidence of both the significance of work stress and its increasing prevalence and impact over time, it is likely that relying on compensation statistics to gauge work stress underestimates the prevalence and significance of work stress (Brijnath et al., 2014; Keegel et al., 2009). The data informing these statistics, collected by Safe Work

Australia, represent only serious claims for compensation (i.e., claims that result in more than one week of absence from work). Further, the process of submitting and having a workers compensation claim approved is complex and difficult (Brijnath et al., 2014; Keegel et al., 2009). For psychosocial claims that are latent in nature, such as work stress, the difficulty is greater when compared with the assessment of physical injury claims. The complexity and involvement of ‘gatekeepers’ (i.e., the claims assessors, assessing medical and professional practitioners, workplace supervisors and management) in having a claim approved is likely to result in underreporting and underrepresentation of work stress. This is in addition to other barriers to reporting work stress, such as mental health stigma (Brijnath et al., 2014; Kirsh et al., 2012) and ‘precarious employment’ (Keegel et al., 2009), which act as deterrents to reporting.

The increasing prevalence of work stress, especially amid a decline in physical occupational injury, reflects the changing nature of work. As a result of technological advances, the types of work available are more taxing mentally and involve less physical labour (Black Dog Institute, 2021; de Jonge & Kompier, 1997; Huneault et al., 2011; Jick & Payne, 1999; NOHSC, 2001). A recent report by the Black Dog Institute (2021) examined how changes in the modern work environment affect the mental health of Australian workers. Workers reported that their jobs were increasingly difficult and complex compared with a decade ago, and they reported increasingly less control in deciding how to achieve the demands of their work (Black Dog Institute, 2021). These factors are related to job strain (Black Dog Institute, 2021), a specific measurement of work stress associated with disease and poor health outcomes (discussed in more detail below), highlighting them as likely contributors to the increased prevalence of work stress in Australia.

This is the case not only in Australia, but also globally, where evidence shows work stress to be a leading cause of chronic illness, lost workdays, and productivity (e.g., American

Psychological Association, 2020; UK Health & Safety Executive, 2019). For example, in the UK, stress, depression, and anxiety were reported to be most prevalent among professional occupations, particularly in the education, human health and social work, public administration, defence, and social security sectors (UK Health & Safety Executive, 2019). A recent study found that the trend in work-related stress, depression, and anxiety in the UK has increased steadily since approximately 2014, and the coronavirus pandemic may have led to a steeper increase in the observed rate (UK Health & Safety Executive, 2021). The effect of the coronavirus pandemic may have had a similar impact in Australia: a recent survey found that Australians were most likely to report the pandemic made their work life more stressful compared to other countries such as the US, Japan and Spain (YouGov, 2022). While the characteristics of work stress may vary among countries and locations, it is clear that the effect of work stress is a global issue.

1.2.3.2 Individual Effects of Work Stress

While discussion related to the economic and business effects of work stress provides incentives for interventions at government and company levels, a thorough discussion of the effect of work stress must also consider the individual experience and outcomes associated with work stress. Epidemiological research shows that work stress is associated with poorer mental and physical health. Using Australian data, Burns et al. (2016) demonstrated adverse mental health and wellbeing outcomes for those experiencing current work stress or transitioning into a stressful work role. Further amplifying the importance of psychosocial risks at work, there is evidence that poor job quality and satisfaction, including experiencing work stress, may be worse for mental health than unemployment (Chandola & Zhang, 2018; Leach et al., 2010). In turn, worse mental and physical health are predictors of reduced labour force participation (Pacheco et al., 2014) and, in some cases, exclusion and unemployment.

Unemployment, especially forced unemployment, significantly affects individual lives, with flow-on effects to families and social networks. These effects are diverse, because the functions and roles of work in life are varied and multifaceted (Clougherty et al., 2010; Fryers, 2006). In terms of financial resources, employment serves many positive purposes for individuals (Odle-Dusseau et al., 2018). Given the social status and high value of working in Western cultures, employment offers individuals protective benefits such as social inclusion and contact, collective purpose, status and identity, time organisation, and regular activity (Fryers, 2006; Jahoda, 1982). There is strong evidence that psychosocial risks (e.g., work stress) that limit inclusion in, satisfaction with, or willingness to work have negative outcomes for the individuals exposed.

Poor employment conditions, including work stress, are increasingly recognised as social determinants of poor health (Clougherty et al., 2010; Marmot et al., 2006). While further research continues to develop the evidence base for this and understand the mechanisms of how it occurs, the negative consequences of work stress are increasingly clear. Subsequently, risk factors, preventative measures, causes, and efficacious treatments surrounding work stress are highly valued areas that benefit not only individual workers, but also companies, organisations, and national economies.

1.3 Job Strain as a Model and Measurement of Work Stress

1.3.1 Defining Stress and Work Stress

Work stress is a specified type of a general stress experience. As such, research on work stress is informed by research on the overarching concept of stress in general. Past research defined stress as the perception of pressures for which the individual did not perceive themselves to have adequate resources to deal with (Lazarus, 1966; Lazarus & Folkman, 1984). This definition focuses on the individual's cognitive appraisals and emotions that arise from their interactions with the environment, known as a transactional

model of stress. Following this transactional conceptualisation of stress, one of the leading accepted definitions of work stress is the ‘harmful physical and emotional responses that occur when the requirements of the job do not meet the capabilities, resources, or needs of the worker’ (Australian Safety and Compensation Council, 2006; Jick & Payne, 1999). Other widely used definitions conceptualise work stress similarly. For example, Houtman and Jettinghoff (2007) defined work stress as ‘a pattern of reactions that occurs when workers are presented with work demands not matched to their knowledge, skills or abilities and which challenge their ability to cope’ (p. 13). Broadly, these definitions emphasise three components that result in a stress reaction: requirements or demands are perceived, the individual’s resources are not sufficient to meet the requirements, and negative or harmful responses occur as a result.

These definitions are broad enough to encompass research on both the antecedent factors and associated consequences of work stress. Antecedents of work stress refer to the study of the physical, social, and psychological aspects of the work itself, the worker, and the work environment that may result in stress. For example, physical antecedents are well defined and identified in research on work stress, including exposure to chemical and other toxic substances; excessive noise, dirt, and temperature levels; confined spaces; and uncomfortable working postures (Keser, 2017; Sonnentag & Frese, 2003). Conversely, psychosocial work stressors arise as a result of interactions between the thoughts, feelings, and behaviours of workers, with factors arising from the workplace such as the social, physical, and structural organisation and experience of work (Keser, 2017). Factors that characterise the experience of the work include job design, management processes (Theorell, 2007), workplace culture (Burton, 2010; Peterson & Wilson, 2002), and workload (Weissbrodt et al., 2018). These factors further characterise the antecedents of work stress (Keser, 2017).

The response to such stressors is regarded as the state of perceived or subjective distress—that is, the experience of stress as a consequence of the antecedent work stressors. The potential consequences of work-related stress may be physical, psychological, emotional, or behavioural in nature. Evidence has consistently related the experience of negative work stress to health outcomes (Clougherty et al., 2010; Jick & Payne, 1999; Marmot et al., 2006; Nixon et al., 2011; Safe Work Australia, 2019; Sonnentag & Frese, 2003). While the terms are often used interchangeably in the literature, stress at work can be delineated from job strain. While stress is not inherently noxious and can indeed be a motivating experience to achieve goals, job strain specifically describes the negative effect on health that is incurred when the experience of work stress becomes noxious (NOHSC, 2001).

To summarise, work stress is recognised as a prominent psychosocial work hazard that can manifest as an antecedent aspect of the workplace (i.e., physical or psychosocial workplace stressors), as a negative reaction in the individual (i.e., experiencing work stress), as both, or as an interaction between both. While there is no single accepted definition of work stress, conceptualising work stress as a transactional model is widely agreed upon, and the key components of experiencing work stress involve individual, situational, and structural elements (LaMontagne et al., 2007).

1.3.2 Measuring Work Stress

1.3.2.1 Job Demands and Control (JDC) Theory and History

The recognition of the negative effects of work stress has led to many attempts to measure work stress, its consequences, precipitants, and associated factors. Of these attempts, the most widely validated and used model is the job demands and control (JDC) model (Van Der Doef & Maes, 1999; NOHSC, 2001). Karasek's (1979) JDC model is based on an interactional (also known as transactional) theory of work stress, whereby work stress is a product of the structural characteristics of a person's interactions with their work

environment (EU-OSHA, 2000). In conceptualising the JDC model, Karasek (2021) stated that an organisation's goals become the job demands placed upon employees in that organisation. Simultaneously, the demands of a job are constrained by the control afforded to employees to meet the demands and achieve the goal. These two central dimensions in the model are termed job demands and job control (also known as decision latitude). While the JDC model subscribes to an interactional theoretical model of stress, the dimensions of the model emphasise the structural characteristics of the workplace in precipitating work stress (Kesar, 2017).

1.3.2.2 Job Demands and Control Dimensions

The job demands dimension of the model captures psychological aspects such as workload, concentration, time pressures, work-related personal conflicts, and unexpected work tasks (Karasek, 1979; Overgaard et al., 2004). Physical demands and other factors that may be considered psychologically demanding (e.g., job instability) are not included. Job control is expressed in two ways: first, through the degree of authority and autonomy afforded to an employee to exercise control over their working day; and second, through the control that an individual has in choosing the strategy and instruments that will best accomplish their workload (Karasek, 1979). These two aspects of job control are known as the decision latitude and skill discretion subscales respectively. Consequently, job control is best defined as both control over decision-making and as a mix of job control and complexity (EU-OSHA, 2000).

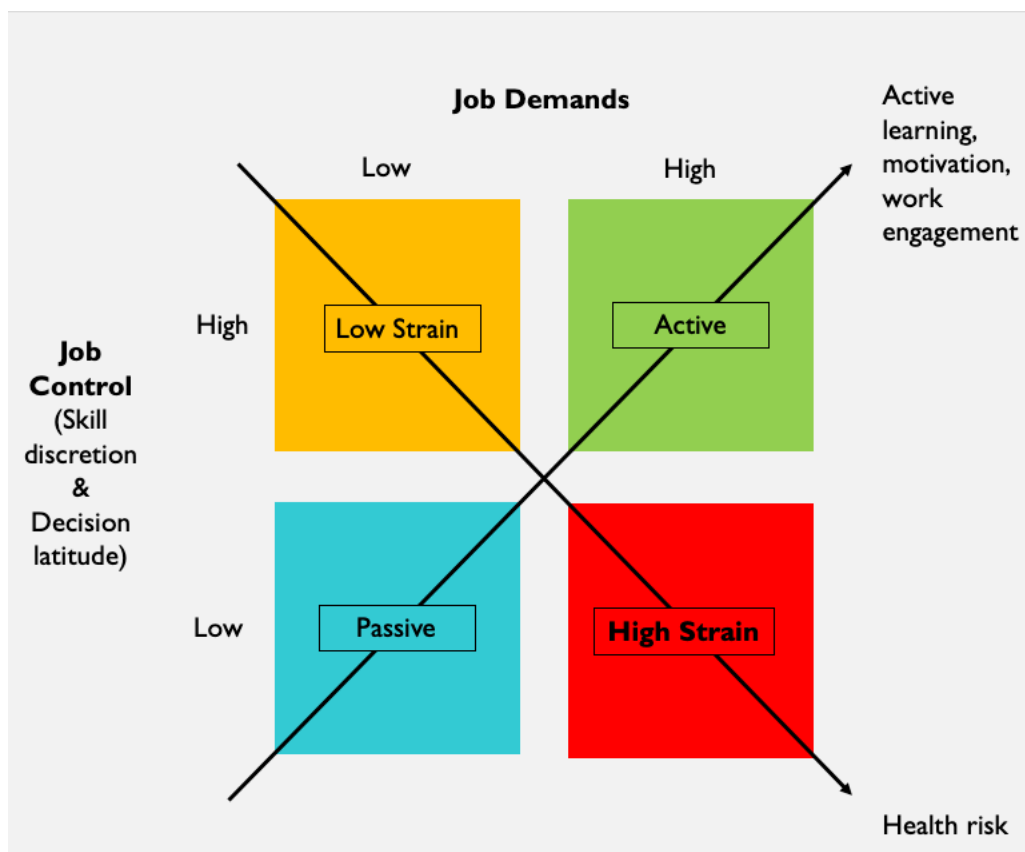
1.3.2.3 Quadrant-Based 'Job Types'

According to the JDC model, increased psychological job demands increases the opportunities and need for learning while simultaneously increasing stress. Conversely, increased job control reduces stress while increasing opportunities for learning and coping (Van Der Doef & Maes, 1999). Figure 1.1 shows how the dimensions of job demands and job

control are modelled, with each dimension moving from low to high (i.e., low or high job demands and low or high job control). Using a quadrant-based approach, four job ‘types’ can be categorised: the first is ‘high strain’, where perceived high demands are coupled with low control over how to meet those demands; the second is ‘active jobs’, where high demands are complemented by high control; the third is ‘passive jobs’, whereby the individual perceives low demands yet has a high degree of control to meet them; and the fourth is ‘low strain jobs’, which refers to the perception of low demands and control (Karasek, 1979).

Figure 1.1

Job Demands and Control Model



Note: Adapted from Karasek (1979) and Niskanen (2017). High strain, the focus of the present thesis, is bolded.

1.3.2.4 JDC Model Hypotheses

Among the varied hypotheses stemming from the JDC model, the job strain hypothesis is a central prediction (Karasek, 1979; Karasek & Theorell, 1990) and is indicated by experiencing high job demands coupled with low job control (see Figure 1.1). The combination of increased stress and the need for learning and coping associated with high job demands, while having limited control to reduce the stress (as a result of constrained opportunities and influence associated with low job control), predicts job strain. The job strain hypothesis is the most widely studied and reliably predicts adverse psychological strain and, by association, the worst health and wellbeing outcomes for employees (Belkić & Nedic, 2007; Karasek et al., 1998; Kivimäki et al., 2015; Lofman, 2018). For this reason, job strain is the focal independent variable under study in this thesis.

The job strain hypothesis is particular in theorising job strain to be a product of both job demands and control, and the levels of each. This specific combination is highlighted by a further hypothesis concerning the active job quadrant, known as the active learning hypothesis. Active jobs, which are characterised by high job demands paired with high job control, predict the working conditions in which motivation, learning, and work engagement are optimised by opportunities to learn new skills, behaviours, and coping mechanisms (de Jonge & Kompier, 1997; Karasek et al., 1998; Siegrist, 2006). The learning opportunities are hypothesised to arise from the specific pairing of high job control resources to meet similarly high job demands, which in turn motivates the development of learning and coping. In contrast to the job strain hypothesis, the active learning hypothesis highlights that it is not high demands in isolation that are theorised to be linked to negative health and wellbeing, but the specific pairing of high job demands with insufficient resources to control how the demands are met.

While the predictions of the job strain hypothesis are primarily concerned with risk for negative health and wellbeing outcomes, the specific relationship between high job demands and low job control in precipitating job strain can be additive or multiplicative (used synonymously with ‘interactive’) (Häusser et al., 2010; Van Der Doef & Maes, 1999). The ‘buffer hypothesis’ specifies that the relationship between job demands and job control is interactive, predicting that job control moderates the negative effects of high demands on health and wellbeing through a multiplicative relationship (Van Der Doef & Maes, 1999). This hypothesis predicts an interaction between varying levels of job demands and job control such that the negative health and wellbeing outcomes associated with the increased stress related to high job demands may be buffered by commensurately high perceptions of influence and control over how to manage the demands. However, empirical support for the buffer hypothesis is more limited than for an additive relationship (Hausser et al., 2010; Van Der Doef & Maes, 1999). Further, while the interactional effect was proposed by Karasek (Van Der Doef & Maes, 1999), in the face of limited support and subsequent criticism, it was clarified that it was not intended as a central focus of the JDC model (Hausser et al., 2010; Van Der Doef & Maes, 1999).

However, there are practical implications that stem from clarifying whether the relationship is multiplicative or additive. As Van der Doef and Maes (1999) explained, if the dimensions operate on a multiplicative interactive basis, interventions aimed at reducing job strain only need to focus on increasing job control rather than reducing job demands. This is because the stress that is hypothesised to arise as a result of increasing job demands should be ‘buffered’ by high levels of job control. This implies reductions in the adverse risk outcomes for health and wellbeing as a consequence of improving job control alone. In contrast, an additive relationship between the two dimensions implies that interventions must focus on levels of both job demands and job control as methods to reduce stress (Van Der Doef &

Maes, 1999; Hausser et al., 2010). This is because the stress associated with high job demands would not be counteracted by increased job control in an additive model. While the practical implications for reducing job strain require clarification of the relationship between the dimensions, reviews and empirical research to date have found more evidence to suggest that the effects of job demands and job control are additive rather than interactive (Hausser et al., 2010; Van Der Doef & Maes, 1999), suggesting that a focus on both job demands and control as efficacious modifiers of job strain is required.

1.3.2.5 Summary of Job Strain

The most prominent hypothesis of the JDC model—the job strain hypothesis—states that workers in high-strain jobs experience the highest risk for adverse health and wellbeing outcomes. While the JDC model does not explicitly measure stress, stress is inferred in the high-strain category (Karasek, 1979), and subsequent research has confirmed links between high-strain jobs and worse physical and mental health, and negative health behaviours (De Lange et al., 2009; Johnson & Hall, 1988; Lallukka et al., 2008; Mausner-Dorsch & Eaton, 2000). It must be noted that stress does not equate to strain, despite being closely linked. While stress (including work stress) can be associated with both negative and positive pressures to achieve outcomes (e.g., ‘active jobs’, whereby job demands are met with high job control), job strain is a more pointed term emphasising the negative valence and undesirable state of work stress that is associated with negative outcomes and hazardous psychosocial risk.

The JDC model and job strain hypothesis fill an interdisciplinary need and provide an instrument that is flexibly suited to social epidemiology, behavioural medicine, and psychosocial studies related to occupational stress and health (Karasek et al., 1998). The job strain hypothesis has been the most widely examined in many disciplines when attempting to measure work stress. The evidence from these studies has consistently supported negative

health and wellbeing outcomes, establishing the validity of the model as a tool for this purpose. Both the quantity of research using the JDC model and the utility of the model in predicting health outcomes make it an accessible and useful measurement instrument, especially in population health research (de Jonge & Kompier, 1997; Karasek et al., 1998; NOHSC, 2001). Other iterations of the JDC model exist (i.e., that also include social support/ broader measures of resources (Bakker & Demerouti, 2018; Häusser et al., 2010; Johnson & Hall, 1988); however, the original JDC model is still well used and validated and was the measure of job strain available for this thesis.

The increasing prevalence and impact of work stress on health and wellbeing (as described earlier in this chapter) drives the need for further research. In synthesising this information, the focus of the current thesis is on examining how negative psychosocial work stress, specifically job strain, may be associated with BMI, an important population health outcome. In particular, the focus is on the risk for increased BMI, which serves as an indicator for adverse health and wellbeing and shares many overlapping associations with job strain. The strong evidence that job strain is associated with deleterious health and wellbeing outcomes, combined with the prevalence and impact of job strain, informs the decision to restrict the scope of this thesis to job strain as the exposure of interest. Restricting the focus of this thesis allows the investigations into job strain with BMI to be comprehensive and detailed, and comparable with the existing relevant literature (which has most often assessed job strain as the key psychosocial exposure).

1.4 Stress and Health

The body of literature, including theory and empirical research, investigating linkages between stress and health is vast. One reason for this is the ubiquitous meaning and usage of stress, which can refer to an external threat (stressor) or a response (Epel et al., 2018; EU-OSHA, 2000; McEwen, 2006; Sonnentag & Frese, 2003). The brain is regarded as integral in

determining stress, because it is the perception of stress, rather than any idiosyncratic feature of the stressor, that is important in initiating the stress response (McEwan, 2006). The varying and sometimes disproportionate stress response of the human body to an objective threat has been well acknowledged (Holmes et al., 2010). However, most agree that there are some stimuli that elicit a stress response across most individuals (Epel et al., 2018; Sonnentag & Frese, 2003).

The stress response of the human body has often been conceptualised as an undifferentiated response that is not unique to any specific stressor (Torres & Nowson, 2007). Further research has since challenged the undifferentiated nature of the stress response (Holmes et al., 2010), and research investigating the complexities of the stress response and associated mediating factors and health outcomes continues (Epel et al., 2018). Despite this, the human body's response to stress, including first-response hormones and biological pathways, seems to be generally well understood and agreed at a broad level (Nixon et al., 2011). The implication of this is that research on stress can be used to inform more niche areas, such as the study of job strain and health.

There are identifiable physiological and biological features of the stress response in the body that indicate the severity of the perceived stress. A broad distinction is stress associated with an acute stress response (i.e., the classic 'flight, fight, or freeze' response) as compared to the stress of everyday hassles that are more characteristic of chronic stress. The 'flight, fight, or freeze' stress response is considered an intense stress response that is rare in contrast with daily hassles, which are considered smaller-scale stressors that are more frequent (McEwen, 2006; Salleh, 2008). Such intense stress responses often present as more episodic in nature, with more easily defined beginnings (i.e., a traumatic event such as a car crash, moving home, loss of loved ones, and unemployment). Often referred to as major life events, the initial intense stress response may also have a more easily defined endpoint,

although the effects of the event may be long-lasting (McEwen, 2006). While there has been much research on stress associated with major life events, acute stress occurring in this manner is not as common as stress associated with daily or regular hassles. The experience of frequent or prolonged, more moderate stress may not have such a defined beginning or end, but through its persistence it may be more related to lifestyle and behaviours (Suvarna et al., 2020), including work life.

According to Karasek et al. (1998), while earlier stress theories centred around the experience of acute stress experiences, the intention of the JDC model was to capture work stress commensurate with more enduring, chronic experiences of work stress occurring as a consequence of complex human interrelationships and organisational structures. In this manner, the JDC instrument and model are suitable for capturing the stress of everyday problems in the workplace. Further, the stress associated with everyday adversity, when experienced over prolonged periods, may be more strongly associated with worse health outcomes (Bean, 2017; Salleh, 2008; Thoits, 2010). Recent evidence suggests that the characteristics of the perceived stressor, such as its intensity and chronicity, are differentially associated with health outcomes (Cohen et al., 2012; Epel et al., 2018; Salleh, 2008; Suvarna et al., 2020). Further, the intensity and duration of the biological stress reaction are influenced by the characteristics of the individual perceiving the stressor, such as personal and interpersonal resources to cope (Siegrist & Rödel, 2006). The next section reviews stress-related health outcomes associated with chronic and everyday stressors. The general biological and physiological stress response associated with both chronic and acute stress is also briefly reviewed.

1.4.1 Biological and Physiological Basis of the Stress Response

The stress reaction occurs through autonomic and neuroendocrine system responses (O'Connor et al., 2021; Suvarna et al., 2020). These systems are controlled through

homeostatic processes, which adapt to the internal and external environment (including perceptions of stressors) to maintain survival (Suvarna et al., 2020). As a part of maintaining homeostasis and responding as needed, the body releases hormones and turns on the autonomic nervous system. Cortisol, adrenaline, and noradrenaline are hormones that are released (known as the primary mediating factors), alongside other metabolic and immune responses, to switch the stress response on and off as needed in response to perceived stressors (O'Connor et al., 2021; Suvarna et al., 2020).

Upon perceiving a threat, the sympathetic adrenal medullary (SAM) system and the hypothalamic-pituitary-adrenal (HPA) axis are activated by the amygdala and hypothalamus, and the autonomic nervous system is switched on (Bergmann et al., 2014; O'Connor et al., 2021). The basic autonomic response occurs as messages are sent to the adrenal glands to release noradrenaline. In tandem, adrenaline is released into the bloodstream by the adrenal medulla. These processes occur in just moments with the purpose of alerting the body and preparing it to act, characterising the flight or fight response.

Cortisol is known as the primary stress hormone because it stimulates the release of glucose in the bloodstream, although it also has other functions within the body (O'Connor et al., 2021; Suvarna et al., 2020). The production of cortisol begins when another hormone released by the hypothalamus—the corticotrophin releasing factor (CRF)—stimulates the pituitary gland to release adrenocorticotrophic hormone (ACTH), which in turn stimulates the production of cortisol. In addition to acting to increase the body's access to energy, cortisol increases proteins and fat mobilisation and decreases inflammation alongside limiting non-essential functions.

Activation of the stress response is not fundamentally noxious, acting to protect the body in the short term. It is when the stress response is chronically activated, or excessively activated more frequently (i.e., experiencing a higher count of acute stressors/life events),

that higher risk is conferred for poorer health and disease (Epel et al., 2018). The process of the stress response adapting the body's homeostatic mechanisms is known as allostasis (McEwen & Stellar, 1993; O'Connor et al., 2021; Suvarna et al., 2020). Excessive and/or chronic activation increases allostatic load, resulting in greater wear and tear on the body's systems (McEwan, 2006). This wear and tear is hypothesised to mediate the direct pathway between the experience of stress and the observations of poorer health and wellbeing. However, there is great individual variability in whether stress will result in poor health or disease (Epel et al., 2018). The degree of reactivity to stress demonstrated in the cardiovascular, endocrine, and immune systems has been linked to poorer health outcomes (Caltabiano et al., 2008). For example, two important ways that excessive activation of these systems affect health are through HPA axis and cortisol regulation, and the autonomic nervous system including the regulation of blood pressure and heart rate variability. Specifically, excessive activation of the HPA axis and prolonged exposure of bodily tissues to elevated cortisol, as well as greater blood pressure and heart rate variability, are some of the causes of the 'wear and tear' on the body described by a higher allostatic load. However, the stress response is a complex phenomenon, and other factors, such as glucocorticoid receptor resistance and inflammation levels, are also important in understanding how stress directly affects health (Cohen et al., 2012; Epel et al., 2018).

While the experience of acute stressors can lead to chronic stress, the most common stressors experienced are low level and operate chronically (i.e., daily hassles) (Caltabiano et al., 2008). Thus, individual coping mechanisms, including evidence based behavioural interventions (i.e., lifestyle medicine) such as exercise and eating behaviours (discussed in more detail below), are important for determining the activation and subsequent impact of the HPA axis. Chronic activation of the stress response is hypothesised to result in dysregulation of the biological systems, including structural remodelling of the brain regions important in

perceiving stress and initiating a response, which in turn results in changed behavioural and physiological responses (Epel et al., 2018; McEwen, 2006; Suvarna et al., 2020).

Increasingly, chronic stress is recognised as the greater risk factor for ill health compared to acute experiences of stress. The increased risk of disease is proposed to be the result of long-term exposure to changes in the body at the cardiovascular, metabolic, neural, behavioural, and cellular levels, resulting in dysregulation of the bodily systems (McEwan, 2008; see McEwen & Seeman, 1999).

1.4.2 Allostatic Load and Chronic Psychosocial Stress

Evolutionarily, the stress response is an adaptive mechanism designed to protect humans by providing physical resources to meet the demands of a given situation to achieve safety. However, when the biological processes associated with the stress response are activated repeatedly or over longer periods, wear and tear on the body occurs, and this is known as allostatic load (McEwan & Stellar, 1993; McEwan, 2006). Allostatic load is a term used to identify, define, and measure the biological, physical, and physiological effects of the stress response on the body. The concept of allostatic load is an important response to the literature, and there is empirical evidence that the physiological effects of stress over time are cumulative and associated with biological ageing and early death (Epel et al., 2004; Suvarna et al., 2020). The direct meaning of allostasis refers to ‘achieving stability through change’ (McEwan, 2008, p. 368; Bean, 2017). Allostatic load is directly related to other theories, such as general adaptation syndrome (Selye, 1936, 1956, 1976, 1985 as cited in Caltabiano et al., 2008), which also attempt to describe biological and health outcomes associated with stress (even over longer periods).

The initiating factors of a stress response (stressors) can be physical or psychosocial in nature—either real or perceived. Subsequently, both can increase allostatic load on the body. In parallel with research on the physical determinants of stress, studies have measured

psychosocial stress and strain for associations with disease and known risk factors for disease (e.g., metabolic syndrome). The bulk of the literature linking psychosocial stress and health has relied upon self-report questionnaires to measure stress, which are commonly regarded as effective measures (Bergmann et al., 2014). While these questionnaires are subjective in the reporting of experienced stress, most individuals report sources of stress to be psychosocial in nature (Scott et al., 2012). It is a well-known possibility that such measures may be biased by state (i.e., affect and mood) and more stable traits (i.e., personality; Chandola & Zhang, 2018). Despite this, the most commonly reported sources of stress include low socioeconomic status (SES), personal conflicts with friends and family, stressful work environments, lack of adequate social support, poor self-esteem, trying to balance home and work life, and caring for a sick loved one (Epel et al., 2018; Scott et al., 2012). Each of these commonly reported stressors reflects both the psychosocial and chronic nature of such stressors: they do not often alleviate quickly. This highlights the importance of investigating chronic stress that is psychosocial in origin, such as job strain.

The combined evidence from the physical and psychosocial bodies of research shows that it is commonly accepted that stress, especially chronic or a higher frequency of episodic stress (i.e., a higher count of stressful or traumatic life experiences), has deleterious effects on health. Thus, it is important for health researchers to be able to identify how, specifically, the experience of stress subsequently affects health. What are the mediating mechanisms? While the allostatic load theory provides a framework to begin to answer this question from its biological and physiological basis, this is an enormous task because, beginning from the initial appraisal of stress, there are biological, psychological, social, and environmental factors to consider, as well as the complex interactions between them. While these mechanisms are not the focus of the subsequent analysis chapters, they are reviewed here for important contextual information.

1.4.3 Pathways Between Job Strain and BMI

To answer the question of what mechanisms might explain the relationship between job strain and health, extensive literature has been undertaken to examine psychosocial working conditions and health outcomes, including BMI as an outcome. The results of direct examinations of job strain with BMI outcomes are somewhat inconsistent, leaving gaps in the literature and the need for further research. The literature and gaps will be thoroughly reviewed later in the appropriate analytic chapters. The intent of this section is to present more peripheral research that supports the existence of a sound rationale to expect that job strain may have a relationship with BMI. While there are large established bodies of research for both job strain and BMI predicting health outcomes that are independent of each other, the peripheral research discussed here is relevant to hypothesised pathways linking job strain with BMI outcomes.

Historically, the small body of research examining associations between work stress and BMI/overweight and obesity was initiated as a potential explanation for, and a complementary investigation of, the evidence of an association between job strain and cardiovascular disease (Niskanen, 2016). Many studies have shown strong support for a relationship between high strain categorisation using the JDC model and coronary heart disease (CHD) (Brunner & Marmot, 2006; Chandola et al., 2008; Niedhammer & Chea, 2003). However, the mechanisms underlying the relationship between job strain and CHD have not been clarified, although they have long been discussed in the literature.

There is evidence for both a direct effect of job strain on biological mechanisms leading to heart disease, and for an indirect relationship through behaviours associated with heart disease (Chandola et al., 2008). Consideration of the potential underlying factors of CHD and job strain have led to the hypothesis that the association may be partly explained by overweight and obesity, because increased BMI is a known risk factor for CHD (National

Heart Foundation of Australia & Australian Institute of Health and Welfare, 2004). However, in addition to explaining the relationship between job strain and CHD, a second rationale for hypothesising a relationship between job strain and overweight and obesity developed from emerging evidence that job strain influenced overweight- and obesity-promoting behaviours, such as reduced physical activity and a lack of exercise, as well as unhealthy diet intake and eating patterns (Marmot et al., 2006; Siegrist & Rödel, 2006). Further research has since demonstrated that job strain may be associated with overweight and obesity not only indirectly through health behaviours, but also through direct biological mechanisms such as diabetes and the metabolic syndrome (Bergmann et al., 2014; Heraclides et al., 2012; Nyberg, 2017; Siegrist & Rodel, 2006).

These direct and indirect pathways form a solid basis through which job strain may be associated with BMI/overweight and obesity, and will be reviewed, drawing on literature from stress in general and job strain specifically where available. Whether these variables are covariates, confounders, moderators or mediators of the relationship between job strain and BMI is certainly an important consideration with subsequent methodological and analytical implications. However, the focus of the thesis is not to investigate the potential mechanisms and pathways, but rather to discuss the evidence for hypothesizing an association between job strain and BMI.

1.4.3.1 Direct Biological Pathways Between Job Strain and BMI

In addition to being a risk factor for disease such as cardiovascular diseases and cancer (Ellison & Ottinger, 2014; Hemingway et al., 2002; Steptoe & Kivimäki, 2012; Theorell & Karasek, 1996), chronic stress has been proposed as a risk factor for the development of the metabolic syndrome and diabetes (Bergmann et al., 2014; Holmes et al., 2010; Nyberg, 2017). The metabolic syndrome is defined by a cluster of individual risk factors, including central obesity (excess adiposity, specifically accumulated around the

waistline), hypertension, insulin resistance (hyperglycaemia), and atherogenic dyslipidaemia (specifically low high-density lipoprotein cholesterol levels and hypertriglyceridemia) (McCracken et al., 2018; Wang et al., 2020). While diagnosis requires the presence of three of these indicators, the metabolic syndrome is not a disease in itself, but is a risk factor for further disease. It is considered a leading risk factor for cardiovascular disease and type 2 diabetes (Wang et al., 2020). Obesity—in particular, central obesity—has been proposed as a leading cause of the metabolic syndrome, tying the development of the metabolic syndrome to physical inactivity and unhealthy diet and eating patterns (given the importance of these factors in developing obesity) (Holmes et al., 2010; Wang et al., 2020). However, the role of stress—particularly chronic stress—in the development of the metabolic syndrome has more recently received increasing attention for its aetiological role.

A meta-analysis of prospective studies found general support for chronic stress to be associated with subsequent development of the metabolic syndrome (Bergmann et al., 2014). Moreover, this review exclusively included prospective studies, leading the authors to conclude that chronic psychological stress is a causal factor for the metabolic syndrome. While the evidence for work stress specifically in relation to the development of the metabolic syndrome was more equivocal in the review, this may be because there is a limited body of research using prospective study designs in this topical area. In contrast, Chandola, Brunner, and Marmot (2006) found a prospective association of job strain on the development of the metabolic syndrome over 14 years. They found that, while control variables such as physical activity, smoking, poor diet, and excess alcohol intake also significantly predicted the development of the metabolic syndrome in males and somewhat in females, these variables were not likely to mediate or confound the significant association found between job strain and the metabolic syndrome. These findings show that the effect of job strain on health behaviours may be independent of the observed risk for the development

of the metabolic syndrome. In essence, the study provided evidence for dual pathways (direct biological and indirect behavioural pathways) through which job strain can be associated with increased BMI and obesity. Supporting this, in a review of the literature, Holmes, Ekkekakis, and Eisenmann (2010) stated that links between chronic stress and obesity are highlighted in particular among research on work stress, as compared to other topical areas examining stress and obesity.

Research on the association between job strain and type 2 diabetes provides further compelling evidence to hypothesise direct biological mechanisms between job strain and health, including BMI. Diabetes is a chronic metabolic disorder concerning the production and regulatory ability of insulin within the body (Ellison & Ottinger, 2014). Type 2 diabetes refers to the insufficient production of insulin, or to a resistance to the effectiveness of insulin, to regulate blood glucose levels, often resulting in abnormally high circulating levels (Nyberg, 2017). Type 2 diabetes can be an acquired disease, with genetic, behavioural, and lifestyle risk factors. In analyses of population datasets, experiencing job strain has been associated with diabetes (Nyberg, 2017) and with the development of type 2 diabetes (Heraclides et al., 2012; Huth et al., 2014). Kivimäki (2017) found robust evidence that job strain is associated not only with diabetes, but also with obesity and physical inactivity, which are the major modifiable risk factors for type 2 diabetes.

Further, disease outcomes that differ by sex are theorised to arise, at least in part, from sex differences in stress reactions (Matud, 2004). These differences are present among the research supporting a link between job strain and health. For example, there are significant clinical implications arising from sex differences in the presentation, prevalence, and aetiology of type 2 diabetes and the metabolic syndrome (Kautzky-Willer et al., 2016; Pradhan, 2014). These differences include varying age of onset for disease, varied aetiological contributors, and varied individual burden of disease impacts (Kautzky-Willer et

al., 2016; Pradhan, 2014). Similarly, differences in the strength of association of job strain with cardiovascular disease and stroke have been observed between males and females (Huang et al., 2015; Johnson & Hall, 1988).

In summary, upon detecting a stressor, the body initiates a stress response designed to assist in adaptively overcoming the demands of the stressor. The stress response is mediated by changes to neural, immune, hormonal, and nervous system activity. However, while adaptive in the short term, chronic or over-activation of the stress response is regarded as a risk factor for ill health because wear and tear on the body (allostatic load) increases as a result of changes to the activity of these systems. Research on the relationship of job strain with the metabolic syndrome and other diseases such as type 2 diabetes and cardiovascular disease, in combination with more general research on the associations of chronic stress with biological and physiological hazards, provides a basis for understanding direct pathways for how job strain may affect health and wellbeing, including BMI.

1.4.3.2 Indirect Pathways Between Job Strain and Overweight and Obesity/BMI: Job Strain and Health Behaviours

Although the study of job strain is specific to the study of stress experienced in the workplace, previous scholars have described the possible ‘spill-over’ of job strain into other areas of life (Choi et al., 2010; Fransson et al., 2012). This spill-over can occur via both the direct and indirect mechanisms theorised to link the experience of job strain with overweight, obesity, and BMI. Some of the main indirect behavioural pathways that have been proposed to link job strain with BMI and overweight and obesity are thought to occur through common behavioural mechanisms for coping with stress. These include reduced physical activity, poorer eating patterns and diet (i.e., increased consumption of comfort foods, poorer nutrition including reduced consumption of vegetables and healthful foods, increased fat intake, and overall increased energy intake), reduced quality of sleep, and increased smoking and alcohol

consumption (Akerstedt et al., 2002; De Lange et al., 2009; Heikkilä et al., 2013; Hellerstedt & Jeffery, 1997; Verweij et al., 2011). These behaviours are also known collectively as ‘lifestyle medicine’, as there is an evidence base linking healthful engagement in these behaviours with positive health outcomes and reducing the burden of chronic disease (Katz et al., 2019).

Further prominent indirect pathways include through the negative association of job strain with broad drivers of health and lifestyle behaviours, such as mental health, physical health, and fatigue (Burns et al., 2016; De Lange et al., 2009; Kompier et al., 2012; Miranti & Li, 2020; Nixon et al., 2011). These may have flow-on effects and interrelationships with many health behaviours that are also linked to BMI and are discussed later in this chapter. This includes a discussion of behaviours directly relevant to the energy balance equation thought to influence BMI, physical activity, and diet and eating patterns. However, a theory is first outlined for why spill-over may occur into these areas of life, and a brief introduction is provided to behaviours related to the energy balance equation thought to influence BMI.

In the below discussion, sex and gender are important contextual factors. There are differences in sex and gender that are thought to occur as a result of differences in the stress-health behaviour relationship—that is, sex and gender differences in patterns of coping behaviourally with stress. Sources and inputs of stress are thought to vary between males and females, with males reporting work as a greater source of stress compared with females, who more often manage work and family simultaneously (Kivimäki et al., 2006). Thus, the exact pathways between job strain and health behaviours are likely to differ among males and females. This is supported in research on job strain and health behaviours, whereby differences by sex are reported, albeit inconsistently at times (Anversa et al., 2021; Griep et al., 2015). Thus, while the sex and gendered differences in these bodies of research are likely to be influential in conceptualising and potentially moderating a relationship between job

strain and health, including BMI, the inconsistencies in the small amount of literature limits the scope of the discussion to elucidate sex differences clearly.

1.4.3.2.1 Job Strain Theory and Health Behaviour Engagement

Choi et al. (2010) discussed Karasek's (1976) construction of the JDC theory of psychosocial work characteristics—specifically, the role of job control in providing workers with opportunities to practice greater agency and skill development. Through engaging in higher-order functions such as the learning process (involving trials to achieve success and overcome failures) and planning, which are defining characteristics of having a job with higher control, Karasek (1976) posited that these skills would be transferrable to other nonwork aspects of the individual worker's life because they create 'feeling(s) of mastery or confidence' (p. 98) and shape 'a more active personality' (Choi et al., 2010, p. 240). Choi et al. further referenced Karasek's discussion of the active–passive hypothesis, highlighting that high job control would be most likely to lead to the transference of these discretionary skills developed at work when combined with high job demands (i.e., active jobs). This is because high job control, in the absence of sufficient demands to use such control (i.e., passive jobs), would not result in the need or motivations for the skill development required to reinforce concepts such as mastery and confidence within the individual worker (Choi et al., 2010). In this manner, the active–passive hypothesis is an early conceptualisation of the importance of high job control in the presence of high job demands for predicting associated nonwork engagement and patterns of behaviour, such as participation in leisure-time physical activity (LTPA), and possibly other health behaviours associated with BMI.

Specific premises from other theories relating to how behaviours may be maintained or modified to enhance health often focus on the skill and ability of individuals to 'actualize a well-conceived plan for the behaviour against barriers in reality' (Choi et al., 2010, p. 241). For example, the theory of planned behaviour, a leading social theoretical explanation of

behaviour, posits that an individual's perceptions of control over the performance of a behaviour are, together with other important elements, influential in determining whether an individual will complete an intended behaviour (Ajzen, 1988, 1991). Further, Staines (1980) found support for the 'spill-over' hypothesis evidencing similarity in the experience of workers' work and family/leisure activities more strongly than differences. Thus, it is plausible to see how a job with higher control, requiring the repeated engagement with and practice of discretionary tasks, may build confidence and mastery for perceptions of control that transfer to nonwork behaviours. By comparison, experiencing low job control in the presence of high job demands (i.e., job strain) reduces the opportunity to develop and reinforce the mastery and confidence, and may spill over to the detriment of engagement with positive health behaviours and other areas in life (Hellerstedt & Jeffery, 1997; Nomura et al., 2010; Wempe & Rosvall, 2005).

1.4.3.2.2 Energy Balance-related Behaviours

The leading basic explanation of increasing adiposity, and subsequently BMI, is an imbalance between the amount of energy consumed (food energy, which refers to any increased consumption of energy regardless of the solid or liquid nature (i.e., drinks also)) and the amount of energy expended (Brunner et al., 2007; Hand, 2013; Hill et al., 2013; Peters, 2003; St-Onge, 2017). Energy expenditure primarily occurs through the basal metabolism and energy expenditure associated with physical activity, although energy is also lost through thermogenetic processes occurring in the body (AIHW, 2021b, 2021a, 2021c; Hand, 2013). If energy consumption is greater than energy expenditure, the body stores the extra energy as adiposity, increasing adiposity levels. If energy consumption is less than energy expenditure, adiposity reserves are accessed and therefore decrease. If energy consumption is balanced with expenditure, no change in adiposity is predicted. This is a very basic explanation, and many factors, such as genetics, neurobiology, and characteristics of

the source of energy, are thought to be implicated in the eventual individual process determining energy balance (Hand et al., 2013; Hill et al., 2013). However, energy balance emphasises the role of food selection and consumption patterns, as well as physical activity levels, when considering the effects of stress on BMI and overweight and obesity. These are considered primary modifiable risk factors for increasing BMI (AIHW, 2021b) and are reviewed below.

1.4.3.2.3 Job Strain, Physical Activity, and Leisure-Time Physical Activity

Physical activity is the greatest source of between-person variation in energy expenditure (Hu, 2013). Reductions in physical activity, influenced by societal and systemic factors as well as individual lifestyle choices, are one of the major causes of the increased prevalence of obesity (McAllister et al., 2009). Physical activity can include intentional and incidental exercise, but it broadly refers to general movement requiring energy expenditure. One challenge with establishing the association between stress and physical activity is the complexity of how physical activity can be defined. For example, household duties require physical activity, as do LTPAs (e.g., hobbies and exercise) and work-related physical activity, all of which contribute to energy expenditure. A summary of the relevant research generally lends support to the existence of links between job strain and increased sedentariness and LTPA (Fransson et al., 2012; Griep et al., 2015; Kouvonen et al., 2005; Nyberg, 2017). However, there have also been some null findings (Goston et al., 2013; Lallukka et al., 2004; Payne et al., 2005); thus, there are inconsistencies within the literature.

Payne et al. (2002) brought together the theory of planned behaviour with the JDC theory in an analysis of individuals' engagement in LTPA. They examined whether there was evidence for cross-over of the JDC theory, through job strain, in both the actual completion of LTPA and confidence (self-efficacy) in one's ability to engage in LTPA. They found that job strain was associated with less engagement in LTPA over the one-week study period,

despite no differences in the *intention* to exercise between those in passive and high-strain jobs. Thus, the authors suggested that the experience of job strain interferes with workers' ability to engage in exercise, rather than interfering with the formation of any intention to exercise. Payne et al. reported that those in high-strain jobs had significantly lowered self-efficacy and perceived controllability, supporting the possible role of work characteristics transferring to perceptions of control relating to, and consequently engagement in, LTPA.

In the largest meta-analysis of individual-level data on job strain and LTPA to date, Fransson et al. (2012) analysed data from 170,162 employees and found that job strain increased the likelihood of physical inactivity by 26% when compared to employees in low-strain jobs. The powerful sample size of the study lends confidence to the results reported and extends clarity to the previous literature, where, although the results of most studies were in general agreement, there were still some equivocal findings. Fransson et al. added further confidence to the reported results by including sensitivity analyses by varying sample sizes. They demonstrated that the effect detected in their study only became statistically significant with a moderate degree of reliability when using a sample size of at least 13,270 (10% of the full sample); however, even with this large sample, the significance value fluctuated above the set alpha (probability level for significance) at times. Given that much of the previous literature on job strain and physical activity was analysed in samples of less than 13,270 participants, Fransson et al. concluded that it is likely that inadequate power was, at least in part, an important factor in the reporting of inconsistent findings among smaller prior studies.

A further explanation for some of the inconsistent findings reported in the literature may be the role of potential moderators of the association between job strain and physical activity. Lallukka et al. (2008) analysed three large epidemiological datasets from three countries—Japan, Finland, and Britain—to compare the association between job strain and health behaviours, including physical activity, in different countries. Their results showed no

consistent patterning of association, with job strain being associated with physical inactivity only for males in Britain and females in Finland. Their research was conducted prior to the conclusions of Fransson et al. (2012) and analysed smaller-than-recommended sample sizes, potentially contributing to the inconsistent results and null findings. However, the nature of their research suggests that there may be slight differences between countries. Currently, there are no data on the association of job strain and physical activity in Australia.

Further, characteristics of the workplace commonly observed among white-collar workers, such as sedentary work, may increase perceptions of stress (Dèdelè et al., 2019). Consistent with this, Yang et al. (2010) reported a longitudinal association of higher engagement in LTPA with a reduced risk for job strain. In their study, reductions in physical activity levels were associated with increased risk for job strain. Further, continuity of exercise habits was important for risk: compared to those who were consistently active over the study, those who had consistently low levels of physical activity had a quadrupled risk for job strain. This suggests that the relationship between job strain and reduced physical activity may be bidirectional and that lower physical activity may affect perceptions of stress, including occupational stress. Thus, the relationship between physical activity and job strain may not be straightforward and may be more complex and cyclical in nature.

Overall, the evidence for an association between job strain and physical activity suggests that job strain is a risk factor for reduced engagement in physical activity and increased sedentariness. This is consistent with the broader literature on stress and physical activity, which often finds positive benefits of exercise and fitness on reducing perceptions of, and reactions to, stress (Gerber & Pühse, 2009; Kettunen et al., 2015). Exercise acts as a buffer to the effects of perceiving stress on the cardiovascular system through strengthening haemodynamic and haemostatic, inflammatory, and neuroendocrine responses (Hamer, 2012). Consistent with this, evidence suggests that cardiovascular fitness, as indicated by

those with a high level of aerobic fitness, is associated with fewer symptoms of burnout and depression, and an increased capacity to handle stress. However, research shows that engagement in exercise tends to decline when individuals are experiencing increased stress (Griep et al., 2015; Heikkilä et al., 2013).

A meta-analysis recommended the workplace as an effective target for increasing physical activity to lower population BMI (Verweij et al., 2011). Physical activity is one of the strongest protective factors for the maintenance of healthy weight and against increasing BMI and the development of overweight and obesity. Physical activity expends energy consumed, rather than that energy becoming stored as excess adiposity, and is regarded as a modifiable risk factor for obesity and morbidity related to increased BMI. Thus, the evidence for job strain being associated with a reduction in physical activity provides a rationale for expecting job strain to be a risk factor for increasing BMI.

1.4.3.2.4 Job Strain, Diet, and Eating Behaviours

The consumption of energy that is not expended accumulates as excess adiposity in the body. As such, unhealthy eating behaviours and poor nutrition that contribute to an energy excess are considered a primary pathway for increasing BMI, overweight, and obesity (James et al., 2013; AIHW, 2021b). It is a well-researched and supported finding that experiencing stress can modify eating behaviours and diet choices (Anversa et al., 2021; Ellison & Ottinger, 2014; Scott et al., 2012; Suvarna et al., 2020; Yau & Potenza, 2013). It is generally less well understood how this occurs, although there is evidence that both overeating and undereating can occur as a result of experiencing stress (Greeno & Wing, 1994). In line with this, there is evidence that stress, including job strain, is associated with both decreasing and increasing BMI (M Kivimäki et al., 2006). There is also evidence that the intensity of the stressful experience is important for determining whether overeating or undereating occurs. A tendency to restrict food intake, and thus undereat, has been linked to

acute, intense stressors (activating the flight, fight, or freeze stress response) (Torres & Nowson, 2007). In contrast, overeating characterises lower-level, more chronic stress experiences that are more representative of daily stressors such as experiencing job strain (Dallman et al., 2003; Torres & Nowson, 2007).

While stress may be linked to decreasing BMI through eating behaviours that restrict the intake of food, the eating behaviours associated with increasing BMI when experiencing stress may be more complex and diverse. The consumption of energy via eating and drinking is a common method of coping with stress (Adam & Epel, 2007; Cummings et al., 2021; Hatzenbuehler et al., 2009). The experience of stress arises from perceptions of demands coupled with the appraisal of insufficient resources to meet those demands. When experiencing stress, individuals appraise their resources to meet or attenuate the demands of the stressor, thus modifying the intensity of the stressful experience. This process is known as problem-focused coping, whereby attention paid directly to the stressor and its causes mitigates its stressful impact (Kim & Jang, 2017; Matud, 2004). However, when individuals perceive that they are insufficiently able to meet or attenuate the demands of the stressor to lessen the intensity of the stressful experience, emotion-focused coping is an alternative, and sometimes complementary, strategy to cope with the stressful experience (Endler & Parker, 1990). Emotion-focused coping involves attempts to modify the negative stressful emotions associated with the stressful problem and is often a less effective method of coping in contrast with problem-focused coping strategies (Kim & Jang, 2017; Matud, 2004). Sex differences have been observed such that females have been found to have greater emotion-focused coping styles than males (Matud, 2004). The coping strategies employed by different individuals are, in part, deterministic of whether the experience of stress is associated with negative or positive health outcomes (Kouvonen et al., 2007; Suvarna et al., 2020).

The use of eating as an emotion-focused coping strategy connects stress with eating behaviours (Kim & Jang, 2017; Laitinen et al., 2002). When experiencing stress, individuals often engage in eating and drinking to provide different and more pleasant feelings as a distraction from the negative consequences and discomfort of the stressful experience (Dallman et al., 2003). Dallman et al. (2003) noted that the use of comfort food as a mitigating strategy for avoiding or redirecting undesired emotional states is an intuitive and well-recognised feature within developed societies. The tendency to engage in eating as an emotion-focused coping strategy may not be problematic if used infrequently. However, the use of eating and drinking to mitigate stress more frequently is likely to result in a positive energy balance, thereby strengthening the connection with increased BMI.

Some key eating behaviours that have been identified for their strong connection to both stress and increasing BMI, overweight, and obesity include the increased selection of convenience foods, preferences for sugary and fatty foods, reduced consumption of fresh fruit and vegetables, and night-time and binge eating (Gluck, 2006; Greeno & Wing, 1994; Grunberg & Straub, 1992; Kim & Jang, 2017). While these eating behaviours do occur independent of each other, it is common to observe varieties of these behaviours co-occurring. For example, the increased selection of convenience foods generally increases the frequency with which sugary and fatty foods are consumed, because convenience foods are often manufactured this way. Foods prepared out of the home, such as processed convenience foods, are often less nutrient dense (Martini et al., 2021). Further, the increased selection of these types of foods reduces the consumption of more nutritious food, such as fresh fruit and vegetables (Guthrie et al., 2015).

Few studies have examined eating as an emotion-focused management strategy specifically for coping with job strain. Nishitani et al. (2009) and Nishitani and Sakakibara (2006) investigated the association between obesity, eating behaviours, and job strain in a

sample of working males. Both studies found evidence that eating behaviours related to emotion-focused coping were associated with increased BMI and obesity in the male workers surveyed. They also found that tension and anxiety reported by the male workers were associated with a tendency to eat to satiety, and with 'eating to reduce irritability' (an avoidance emotion-focused coping strategy) (Nishitani & Sakakibara, 2006; Nishitani et al., 2009). While they did not find a direct association between the components of job strain, decision latitude, and job demands with eating behaviours, Nishitani and Sakakibara (2006) found that the emotion-focused eating patterns were related to tension and anxiety, which were in turn related positively to job demands and negatively to decision latitude. Thus, while there may be an intricate pathway involving mediating factors, the authors found broad evidence that stressful working conditions may influence eating behaviours, which in turn contributes to increasing BMI.

While research on stress and eating behaviours is abundant, there is scarce research examining the associations between job strain and eating behaviours (Kawakami et al., 2006; Santana-Cárdenas, 2016). Examination of the results of the few studies that are available have demonstrated inconsistent and null associations (Lallukka et al., 2008). A systematic review by Santana-Cardenas (2016) examined studies reporting on the association between eating habits, obesity, and work stress more broadly. It found that half of the studies supported a positive association between work stress and obesity, and one-third supported an association between work stress and disordered eating. Methodological differences among the studies reviewed included different scales measuring work stress and eating behaviours, and different study selection and analytical methods. These differences made comparisons difficult and potentially confounded the results. Despite this, Santana-Cardenas concluded that there was sufficient evidence to warrant further investigation of the influence of work

stress on eating behaviours and its subsequent contribution to increasing BMI, overweight, and obesity.

Although few in number, some studies not included in Santana-Cardenas's (2016) review have examined job strain in relation to eating behaviours. Hellerstedt and Jeffery (1997) found that high job demands were associated with higher intake of dietary fat among a sample of male workers in the United States (US), while Lallukka et al. (2004) reported that low job strain was associated with healthy diet intake among female workers from Helsinki. A further large epidemiological study examining a cohort from London and Helsinki did not find an association between the job quadrants of the JDC (strain, active or passive jobs, relevant to low-strain jobs) and unhealthy food habits (Lallukka et al., 2008). Taken together, there is no consistency among the results reflecting the varied evidence reported by Santana-Cardenas (2016). The heterogeneity in the findings is understandable if considered in light of research by Hill et al. (2021), who noted that the area of stress and eating involves many complex and confounding factors that lead to a large degree of heterogeneity observed among the relationships. In particular, Hill et al. noted that not all individuals experience altered food intake as a result of stress, and of those who do, chronic stress can be associated with both over- and undereating. This was identified among other moderators of the relationship such as sex, age, and baseline BMI. In an associated meta-analysis to further investigate the relationship between stress and eating, Hill et al. reported a robust positive relationship of stress with an overall increase in food consumption. Simultaneously, they reported that the consumption of healthy foods decreased, while the consumption of unhealthy food increased, in association with experiencing stress. However, they noted that the size of the relationships estimated was small, and that investigations into potential moderators were not comprehensive in explaining the significant heterogeneity observed in the stress and eating relationship.

This heterogeneity in the relationship of stress with eating provides a further insight into the inconsistent evidence found in research on job strain and eating. While the empirical evidence supporting an association between job strain and eating behaviours is limited, the available research suggests it is a possibility, and resting upon the larger body of research of stress and eating in general provides a solid basis to expect a relationship (i.e., Anversa et al., 2021; Hill et al., 2021).

1.5 BMI: Measurement, Trends, and Health Risks

In Australia, as reported on a global scale, there is an epidemic of people becoming overweight and obese. Underlying the increases seen in the proportion of overweight and obese individuals, both the mean and right skew of the population BMI distribution is increasing (Hayes et al., 2015). This is problematic at a population level because the burden of disease and risk for developing disease increases as BMI increases to higher values (escalating past the overweight and obese category cut-offs). Further, there is emerging evidence that variation in BMI—even modest increases over time—increases the risk of poorer health and developing disease (Stommel & Schoenborn, 2010; Zheng et al., 2017). In the search to identify, and thus target, modifiable contributors to the increasing trend seen in the BMI distribution, many different facets of life are under exploration. The study of the workplace and workplace characteristics is one such area being considered.

The focus of the above section was on stress and health, covering some of the key direct and indirect pathways between the experience of stress and adverse health outcomes. The following section will focus on describing BMI measurement and distribution, as well as the utility and importance of BMI for health, using a population health approach. Broad health outcomes associated with BMI (including overweight and obesity categories) and variation in BMI will be discussed. This discussion sets the scene for how BMI is operationalised and conceptualised within the analytic chapters later in the thesis.

1.5.1 BMI: Background Information

As explained above, at the most basic level, excess fat is gained through a positive energy imbalance, whereby the amount of energy consumed exceeds that which is expended (WHO, 2013). Excess energy is stored as adiposity in the body and increasingly accumulates unless expended. A certain amount of body fat is optimal and vital to healthy functioning; however, an increased disease risk manifests when the amount of fat carried within the body exceeds the optimal amount required (James et al., 2001).

The most widely used measure of excess fat is the BMI, which is calculated by dividing an individual's weight in kilograms by their squared height (i.e., kg/cm^2). While essentially a continuous measurement, BMI is often categorised as underweight (<18.5), normal weight ($18.5\text{--}24$), overweight ($24.1\text{--}30$), or obese (>30) according to internationally accepted cut-offs (WHO, 2000). The obese category collectively describes those individuals whose BMI is 30 or higher. The increasing prevalence of the number of obese individuals coupled with the presentation of ever-greater BMIs (ABS, 2013b; Finucane et al., 2011; Sassi et al., 2009) has led to the obese BMI category being divided into three subclasses of obesity: obese class 1 describes BMIs in the range of $30\text{--}34.99$; obese class 2 refers to $35\text{--}39.99$; and obese class 3 describes those above 40.

BMI categories show significant correlations with health and disease indices and economic burden as expected (James et al., 2001; WHO, 2000, 2013). However, BMI is not a measure of excess fat explicitly but of total body mass, which comprises all bodily tissues or elements such as muscle, bone, and water weight, alongside depositions of fat. Thus, BMI can be misleading because healthy individuals with heavier body compositions can be misclassified as overweight or obese (Ogden et al., 2003). Other limitations that contribute to BMI misclassification include the systematic over-reporting of height and under-reporting of weight (Flegal et al., 2019). Other known systematic biases in BMI include the over-

estimation of BMI below BMIs of 22, and the underestimation of those over 28 (Stommel & Schoenborn, 2009). These systematic biases are also known to differ by socio-demographics such as age, with evidence that middle-aged individuals report BMI more accurately than younger and older individuals (Stommel & Schoenborn, 2009). Further, there are other known limitations with the use of BMI as an indicator of health risk, including the distribution of excess adiposity within the body. Measures of central adiposity, such as WHR and WC, indicate excess adiposity disproportionately distributed and accumulated centrally on the body. Excess adiposity closer to the internal organs demonstrates stronger associations with health and disease outcomes (Haregu et al., 2020) and there is evidence that chronic stress is associated more strongly with a central accumulation of excess adiposity (Dallman et al., 2005).

These limitations, including systematic biases, increase the error variance in BMI and may weaken the associations observed between the true presence of excess fat and health and disease indices. However, correlations between BMI and more specific indicators of excess adiposity—rather than of body mass generally, such as abdominal visceral fat and excess fat mass—range in the mid-90s (a slight variation is observed between studies); thus, there is strong evidence that BMI is a very good indicator of excess adiposity in population research (Bouchard, 2007).

1.5.2 Trends in BMI Impact and Prevalence of Population BMI/Overweight and Obesity

While the present thesis is primarily concerned with BMI, overweight and obesity are categories of BMI intended to indicate heightened risk for poor health and disease, especially in epidemiological research examining population health. Increases in BMI are the mechanism through which overweight and obesity are achieved. Given that the basis of overweight and obesity is BMI, the findings of studies examining each are often related.

Although there is great overlap, there are also differences when focusing on one outcome, especially at the exclusion of the other, which will be highlighted throughout this thesis as appropriate. Overall, this thesis presents the examination of BMI and overweight and obesity as complementary; the study of each provides further context, which deepens the general understanding of excess adiposity and population health. This section discusses the importance of not solely focusing on overweight and obesity categories, and highlights the importance of examining BMI at a population level.

1.5.2.1 Overweight and Obesity

There is now a large body of research, knowledge and rhetoric surrounding overweight and obesity. Since 1980, when nationally representative data first became available, there has been an alarming increase in the number of overweight and obese Australian adults and children (ABS, 2013b; Finucane et al., 2011; Sassi et al., 2009). This increase is commonly termed ‘the obesity epidemic’ and has been labelled a public health crisis by leading world and national authorities (National Health and Medical Research Council, 2013; WHO, 2000). Australia has one of the highest prevalence rates of overweight and obesity among developed nations and OECD countries (Grima & Dixon, 2013; OECD, 2017). The urgent attention paid to the rapidly growing population of overweight and obese individuals is due to the considerable detrimental economic and health consequences associated with overweight and obesity. Overweight and obesity are classified as non-communicable diseases, and the WHO (2013) lists them as the fifth leading cause of death globally. This is because they are a significant risk factor for other non-communicable diseases such as type 2 diabetes, heart disease, various types of cancers, and mental disorders (Calle & Kaaks, 2004; National Health and Medical Research Council, 2013; WHO, 2000).

For individuals, the impacts of overweight and obesity are further accentuated by a large body of evidence suggesting that overweight and obesity detrimentally affect physical

mobility (increasing the risk for both chronic and acute disability), life satisfaction (Ball et al., 2004), career advancement (Bento et al., 2012; O'Brien et al., 2012), and self-esteem (Ogden & Clementi, 2010), among others. While the personal effects of overweight and obesity are highly varied between individuals, the risk and burden associated with them coalesces across individuals. At the economic level, the total cost to Australia was estimated to be as high as \$21 billion annually (Colagiuri et al., 2010). This estimate included both direct costs, such as attributable costs to the healthcare system, and indirect costs, such as lost productivity. More recent estimates of the annual productivity loss associated with obesity were as high as \$14.9 billion annually (Crosland et al., 2019).

There has been a dramatic increase in the number of people classified in the obese ranges in the past few decades, partly as a result of the more general upward shift observed in the population distribution of all BMIs (Finucane et al., 2011; James et al., 2001; Sassi et al., 2009). Thus, there have also been increases in the number of individuals classified as overweight (Ng et al., 2014; The GBD 2015 Obesity Collaborators, 2017). Accordingly, just as the burden of disease caused by obesity has increased, the burden associated with being overweight has also increased (Colagiuri et al., 2010; Finucane et al., 2011).

There are clear and significant incentives at both the personal and economic levels for individuals to remain at a healthy weight. Further, the cost and ease of preventing BMI increase leading to overweight and obesity are far less than treating and reducing overweight and obesity (Hill et al., 2013; Lemmens et al., 2008). However, despite this, there is currently no country that is able to serve as a model for curbing the increasing numbers of overweight and obese individuals (Ng et al., 2014; Swinburn et al., 2011). Further, there are no widely accepted methods that have proven effective at maintaining weight loss in the long term across populations (Jeffery et al., 2000). This highlights the need for further research that aims to better understand the factors that are instrumental in the development of increasing

BMI, and to assist in producing evidence-based best practices for intervention and prevention of overweight and obesity and the promotion of healthy weight maintenance.

1.5.2.2 Distribution of BMI

The broad issue that underlies the pathway to both obesity and overweight is BMI increasing over time. In general, BMI is accrued across the lifespan, and there are calls to examine BMI as a distribution, including how the distribution of BMI is changing and ‘accruing’ over time (Hayes et al., 2015). It is widely known and evidenced that the BMI distribution average is increasing ever higher, and that the right skew of the BMI distribution is also increasing (Nuttall, 2015; Pasco et al., 2013; Penman & Johnson, 2006). These trends reflect that individuals’ body weights are heavier (increasing BMI), that more individuals are overweight and obese than ever before (Ng et al., 2014), that the proportion of underweight individuals has decreased over time, and that extreme BMI values are becoming more frequent than previously (Hayes et al., 2015; VicHealth, 2013). However, research shows that distributional patterns differ based on subpopulations and select characteristics such as age and sex (Hayes et al., 2015, 2019; Huse et al., 2018; Peeters et al., 2014).

The distribution of BMI according to age reflects the statement that BMI generally accrues over time. For example, mid-life adults have the heaviest average BMI compared to younger and later-life adults, with average BMI in Australia tending to decline after approximately age 74 (Aarestrup et al., 2016; ABS, 2018; Huse et al., 2018; Zheng et al., 2017). This is reflected by prevalence data reported for Australia in 2017–2018, which showed that 46% of those aged 18–24 years were overweight or obese compared to 68.7% of those aged 35–44 years (ABS, 2018). In Australia, males tend to have a higher prevalence of overweight and obesity combined, and consequently a greater right skew in the distribution of BMI. However, females tend to have higher proportions of extreme BMI values, although similar proportions of obesity to males (AIHW, 2017; Vic Health, 2013). In contrast, global

data suggest that females tend to have a higher prevalence of overweight and obesity than males (Chen et al., 2019). Other important social determinants that show distributional differences in BMI include living area (rural versus urban locations) and markers of SES.

Structural characteristics of the neighbourhood and living area that account for lower prevalence of overweight and obesity include access to playgrounds, green spaces, and recreational areas, and easy access to healthy foods (i.e., presence of close supermarkets) (AIHW, 2017). Reflecting the importance of these features, living in major cities is associated with a reduced likelihood of overweight and obesity. These beneficial structural characteristics of the lived area often reflect higher socioeconomic indicators. Unsurprisingly, BMI distributions are strongly associated with levels of SES, known as the SES gradient of overweight and obesity (AIHW, 2021b, 2021a; Markwick et al., 2013; Masood & Reidpath, 2017). There are many indicators of SES, although education appears to be robustly associated with BMI distribution (AIHW, 2021a). In Australian data, higher education is consistently associated with a reduced likelihood of overweight and obesity (AIHW, 2021a; Hayes et al., 2015, 2019) and a lower prevalence of overweight and obesity. Hayes et al. (2019) noted that the association between education and BMI is likely greatly emphasised in modern times given the changing access to and importance of education in society.

1.5.2.3 BMI Change Over Time

In parallel to observing the distribution of BMI at any point in time, it is important to understand changes in the BMI distribution over time. This helps to inform the understanding of how BMI accrues to detrimental levels (i.e., overweight and obesity). BMI is not a static feature of an individual; rather, it is an indicator of body mass that is a dynamic state regarded as representing changing levels of adiposity in population health research (Nuttall, 2015). Just as the shape of the BMI distribution changes depending on subpopulations and characteristics, there is also evidence that the rate of BMI change over time varies among

subpopulations and by differing characteristics, such as age and sex. For example, there is evidence that females tend to gain weight at a faster rate over time than males (Haby et al., 2011). Regarding stage of life, young adults have consistently been shown to have greater increases in weight, and thus BMI, compared to mid-life and older adults (Hayes, 2015; Peeters et al., 2014). Young adulthood is the period during which most individuals accrue their BMI, which is consistent with mid-life adults having the greatest average BMI and higher proportions of overweight and obesity.

It is important to understand the variability in BMI increases over time because it provides critical information for predicting health challenges and identifying areas for intervention to reduce the burden of disease. Hayes et al. (2015) compared Australian data from the 1980s with data from the early 2000s to assess whether there were differences in the rates of annual BMI gain by period. They found that annual BMI gain was the same across both periods, although the average BMI was higher among the younger cohort. This reflects the increasing average of BMI and that, while BMI accrual was the same among the cohorts, period effects meant that the younger cohort entered young adulthood with higher average BMI than the previous cohort. The higher average BMI attained earlier in life was associated with poorer health predictions for this cohort (as a result of a greater length of time living with increased BMI and number of ‘obese years’) (Abdullah et al., 2012) and with greater mid-life overweight and obesity as this cohort aged. Further, other studies have shown that the rate of annual BMI increase is greater among those with more severe levels of obesity, exacerbating the underlying increased risk (Huse et al., 2018; Keating et al., 2015; Lung et al., 2019; Walls et al., 2012).

A recent microsimulation of adult obesity in Australia reflected these trends, with predictions of ‘unprecedented levels of obesity and severe obesity by the time they [younger birth cohorts] reach middle age’ (Hayes et al., 2019, p. 3). In this simulation study, rates of

BMI increase were modelled according to SES, which was predominantly specified by education. Evidence generally shows that higher SES—in particular, higher education—is associated with lower rates of BMI increase over time (Peeters et al., 2014). The microsimulation examined predictions of BMI increase over time that are important for the future prevalence of overweight and obesity, finding that BMI increase was greater among those of lower socioeconomic position. Hayes et al. predicted that the current socioeconomic inequality in obesity rates would persist at a minimum, but was more likely to widen over time, meaning that by middle age and older, more recent birth cohorts would see greater increases in obesity and consequently experience a significantly worse burden of disease. Thus, the socioeconomic gradient of obesity and BMI increase represents a current threat to the equality of health in Australia and is predicted to worsen (VicHealth, 2013; Hayes et al., 2019).

Population data suggest that the rate of BMI increase may have slowed. Peeters et al. (2014) aimed to assess the evidence for this in the Australian population by comparing annualised weight gain in the same adults over two periods (measured at three occasions: 1999/2000, 2004/2005, 2012). They found that annualised weight gain significantly decreased in the second period, especially for mid-life adults. However, despite finding a slowing in the rate of increase overall, weight gain was still increasing over time. Further, for those with the lowest SES, no slowing was found, again highlighting the importance of the differential gradient in BMI, overweight, and obesity occurring across SES levels. Findings from Huse et al. (2018) further support the notion that the overall rate of weight gain may have slowed. When analysing significant differences in the prevalence of overweight and obesity combined, the comparison of the prevalence data between 1995 and 2014/15 showed a significant increase of 5.6%. However, the increase in prevalence data from 2011/12 to 2014/15 showed no significant difference in the general population for either sex. This

supports the rate of increase slowing over this period, although further data may show significant increases as more time passes.

Although the rate of BMI increase has been found to vary according to certain factors, one notable highlight is that, in general, BMI increase is a relatively slow phenomenon. In their analysis of population trends, Peeters et al. (2014) estimated annualised weight gain to be 0.13 kilograms per year between 2004/2005 and 2012, and 0.34 kilograms per year between 1999/2000 and 2004/2005. In an earlier estimate, Haby et al. (2011) predicted BMI in the Australian population to increase by 0.07 and 0.10 BMI units annually for males and females respectively, which would increase rates of overweight and obesity combined by an estimated 0.4–0.8% per year between 1995 and 2025. Thus, the burden of disease associated with overweight and obesity is considerable at both the economic (e.g., financial) and individual (e.g., poor health) levels (among others). The evidence suggests that these outcomes will worsen over time, and more vulnerable and high-risk groups will experience a worse burden of disease due to a faster rate of BMI increase. Despite these differences, the mechanism of increasing adiposity, which leads to weight gain and subsequently a BMI increase, occurs in populations relatively slowly over time.

1.5.2.4 Health Risks and BMI Changes

The research outlined here provides evidence that investigating the continuum of BMI is important and complements research that is focused on overweight and obesity defined as categories. Others similarly recognise these benefits but note that there is inadequate research and tracking in this area, calling for further research investigating the influential factors and associations with the population BMI distribution (Chen et al., 2019; Huse et al., 2018; Ng et al., 2014). Health risks associated with overweight and obesity occur across a continuum and do not begin at the cut-points of the overweight and obese BMI categories (Haby et al., 2011; Lohse et al., 2017; Preston et al., 2015). While the categorisation of overweight and obesity is

a useful indicator for health risk, especially when considering population health, the selected cut-points are considered arbitrary given the continuous nature of the underlying health risks (Haby et al., 2011; James et al., 2004; Stommel & Schoenborn, 2010).

Increasing BMI conveys an increased risk for poor health and disease outcomes (Stommel & Schoenborn, 2010). This is because BMI is designed to reflect body mass, and this is in turn used as an indicator of adiposity levels, which are continuous and not categorical. Subsequently, while overweight and obesity are categorised to convey large and standardised health risks, the health risks associated with increasing adiposity can also be quantified in smaller and more relative ways (Lohse et al., 2017). For example, a more recent approach to examining health risk associated with adiposity (and thus weight and BMI) focused on how stable or variable the levels were and over what period. Evidence suggests that change, including BMI increases and decreases over time, is linked to poorer health outcomes such as CHD, cancer, and mortality (Chen et al., 2019; Karahalios et al., 2017). Evidence that change is important has been found across varying life periods, including from early adulthood to mid-life, and from mid-life to later mid-life (Chen et al., 2019; Karahalios et al., 2017; Zheng et al., 2017).

The evidence that change in BMI is important for health risks also implies that stability in BMI is important for maintaining healthy ageing across the life (Chen et al., 2019). This approach to understanding the relationship of BMI and health is a more relative approach than using overweight and obesity as indicators exclusively, because the variation associated with health risks occurs within overweight and obese categories and is relative to the individual's BMI at the beginning of the period of observation (e.g., early adulthood, mid-life) (Stommel & Schoenborn, 2010). However, the relationship between overweight and obesity and change in BMI is not mutually exclusive and may interact or be additive in its association with health outcomes, just as the maintenance of normal weight across adulthood

may have the greatest association with healthy ageing and reduced health risk (Chen et al., 2019).

Other factors are also relevant to characterising the relationship between BMI over time and health. ‘Obese years’ represents the number of years an individual’s BMI is categorised as obese (Abdullah et al., 2012). Evidence suggests that this is a further factor that contextualises the relationship between BMI and health risk, with increased health risk given a greater number of years lived with obesity (Abdullah et al., 2012). For example, in research examining BMI at different life stages, consistent obesity from early to mid-life presents an increased risk of poor health and mortality (Chen et al., 2019). Abdullah et al. suggested that the combination of degree (the health risk with increasing BMI) and duration (the construct of obese years) of obesity may better represent the relationship between BMI and health outcomes and risk.

The established health risks associated with overweight and obesity are valid and useful in research, but further information regarding variations across time, as well as other factors such as ‘obese years’, is important in understanding the relationship between BMI and health. The relationship is not likely to have a simple explanation, and this section has highlighted some of the complexities that lead to advocating for the examination of BMI as continuous across the distribution, across time, and as complementary to investigations focused on overweight and obesity.

1.5.3 High-Risk v. Population Intervention Strategies

The information outlined above advocates the need to focus on BMI increases across all individuals rather than examining overweight and obesity as primary outcomes alone. The examination of continuous BMI aligns with a public health approach whereby even modest shifts in BMI distribution over time are associated with important implications and are often the focus of interventions. This approach draws on theory outlined by Rose (1992), which

discusses how small change in a population may be more efficacious in reducing the impact of non-communicable disease than interventions targeted at only high-risk individuals. Specifically, Rose (1992) proposed that a leftward shift in the population distribution of BMI overall may have a greater effect on the long-term incidence and prevalence rates of comorbid diseases than interventions aimed at reducing comorbid disease in individuals already presenting as overweight or obese exclusively. Importantly, this notion has been tested in hypothetical models using Australian population data (Brown et al., 2007), and it has been supported in a real-world context using data from before, during, and after Cuba's economic slowdown between 1980 and 2010 (Franco et al., 2013).

Brown et al. (2007) used data from a nationally representative survey of Australian women to model the effect of a one-point reduction in BMI across the population as a whole to estimate the hypothetical effect on the incidence of comorbid hypertension and diabetes. The results from this scenario were compared with those from modelling a high-risk intervention strategy, whereby a three-point reduction was applied to those with a BMI of 29 and above only. It was found that the benefits were greater for hypertension incidence using the population strategy, but that incidence rates for diabetes benefited from the high-risk intervention strategy. However, a third approach theorised by Rose (1992), termed a 'middle-ground' approach by Brown et al., demonstrated greatly reduced incidence rates for both hypertension and diabetes compared with either of the other strategies. The middle-ground approach involved examining the incidence of comorbidity with increased BMI more closely, which Rose (1992, as cited in Brown et al., 2007) described as a J-shaped distribution. In this distribution, comorbidity is relatively low at stable levels until a certain point at which it begins to rise, and as it continues, the gradient of the slope becomes steeper (in a curved manner). The middle-ground approach involved a modest two-point reduction in BMI for only the upper half of the population (from a BMI of 24 onwards) (Brown et al., 2007).

While Brown et al.'s (2007) results, which provided support for Rose's (1992) proposed population intervention approach, were only hypothetical, real-world support for the strategy was reported by Franco et al. (2013). Using data from cross-sectional surveys collected before, during, and after Cuba's economic slowdown, Franco et al. showed that a leftward shift in the population distribution of Cuba's BMI was associated with a reduction in the incidence and prevalence of diabetes, coronary mortality, and all-cause mortality. In both studies, the loss of around five kilograms (equivalent to a two-point reduction in BMI) was enough to influence the findings of each investigation, supporting the notion that modest changes in the BMI population distribution (and subsequently in individuals) can result in influential outcomes. While the current thesis does not examine intervention strategies explicitly, the above research supports two key messages of this thesis: a) that broad social determinants such as job strain are potentially important drivers for the BMI distribution, and b) that the investigation of a more modest change in BMI is equally as beneficial as the examination of overweight and obesity categories explicitly.

1.6 Rationale for Positing an Association Between Job Strain and BMI:

Possible Mechanisms

The previous sections of this introduction discussed the importance and implications of job strain from a public health standpoint, provided a summary of the relationship between stress and health, as well as evidence of specific linkages between job strain and health, and introduced BMI with contextual information highlighting the importance of increasing BMI as a public health priority. This section examines factors that are more complex in their association with job strain and BMI, such as mental and physical health, and fatigue.

The most direct mechanisms through which to theorise a relationship between job strain and BMI are the energy balance-related behaviours and disease outcomes described earlier. These pathways were discussed as direct (biological) and indirect (behavioural)

pathways connecting job strain and BMI. Further to these mechanisms, mental and physical health and fatigue are suggested as more diffuse factors that may underlie and connect job strain, health behaviours, and BMI increase. These particular factors are more diffuse because, while there is substantial evidence suggesting that job strain is associated with these broad factors, these factors are in turn associated with health behaviours. This elucidates a more complex network of pathways through which an association of job strain with BMI may develop.

1.6.1.1 Fatigue as a Way of Connecting Job Strain and BMI

Fatigue is one possible contributing mechanism to explain some of the overlapping factors that may connect job strain and BMI. The experience of job strain is hypothesised to be associated with the need for greater recovery and rest time as a result of increased fatigue from strain (Fransson et al., 2012; Kompier et al., 2012; Lallukka et al., 2004; Sembajwe et al., 2012). According to De Lange et al. (2009) and Kompier et al. (2012), together, the effort-recovery and allostatic load theories can provide a structure to understand how job strain leads to fatigue. The experience of strain in the absence of adequate recovery, especially as a result of prolonged or repeated exposure to the stressor (i.e., daily encounters of job strain), may cause homeostatic imbalances between the activity of the sympathetic and parasympathetic nervous systems that may subsequently manifest as ill health or increased risk for ill health (De Lange et al., 2009). Physical fatigue is a symptom of the hypothesised transfer of these homeostatic imbalances towards ill health that occur over time. However, fatigue is also commonly reported as a side effect of stress regardless of the duration of the stressful experience, likely reflecting the physical energy expenditure of activating the HPA axis and the associated stress-response pathways in the body.

The relationship between job strain and increased fatigue levels may have flow-on effects for increased BMI because experiencing fatigue is a risk factor for increased BMI and

overweight and obesity. Fatigue is a commonly reported barrier to engagement in LTPA and healthy eating, and is associated with both physical illness and poorer mental health and distress (Bültmann et al., 2002; Pawlikowska et al., 1994; Resnick et al., 2006; Williamson et al., 2005). Reductions in physical activity and poorer eating choices are energy balance–related behavioural patterns theorised to increase adiposity and increase BMI. Reductions in physical and mental health and wellbeing are known to influence choices and opportunities, which, in turn, are associated with energy balance–related behaviours, increasing the risk for BMI increase, overweight, and obesity. Thus, fatigue associated with job strain is one explanatory mechanism through which the experience of job strain may culminate in behaviour modification and shape broad underlying factors such as mental and physical health, which, in turn, are related to risk for higher BMIs and overweight and obesity.

1.6.1.2 Mental and Physical Health as a Way of Connecting Job Strain and BMI

Mental and physical health are vital components of maintaining optimal health (WHO, 2020). Being employed is often associated with better mental and physical health (Broom et al., 2006; Butterworth et al., 2010; Pacheco et al., 2014). However, experiencing job strain is associated with declines in mental and physical health, and also with both mental and physical health conditions (Burns et al., 2016; Lofman, 2018; Nixon et al., 2011). Job strain is a construct designed to represent psychosocial characteristics of the workplace, specifically noxious stress appraisals and experience. Thus, job strain has been found to be an important factor in psychological wellbeing and is predictive of mental health conditions. Job strain has been found to have strong associations with varying levels of depression, including subsyndromal, minor and major depression, dysphoria, and depressive syndrome (Burns et al., 2016; Mausner-Dorsch & Eaton, 2000). Research suggests that job strain approximately doubles the risk for depression, even after accounting for other known risk factors (LaMontagne et al., 2007, 2010; Stansfeld & Candy, 2006). Further, there is evidence that job

strain confers a prospective risk for depression (Mausner-Dorsch et al., 2000). Entry into a high-strain job has been associated with the onset of depressive symptoms, while exit from a high-job strain has been associated with an alleviation of depressive symptoms (Burns et al., 2016). These patterns of association have been described as consistent with causal mechanisms for depression, highlighting the importance of psychosocial characteristics of work—in particular, job strain—for mental health and wellbeing.

Job strain has also been associated with declines in physical health, including physical health conditions and disease outcomes. The mechanism theorised to mediate the pathway between the experience of job strain and physical decline is the stress response—in particular, the exposure to chronic stress as described earlier in this chapter (Brunner & Marmot, 2006; Mauss et al., 2015; Siegrist, 2006; Siegrist & Rödel, 2006). Many of the associations between job strain (and stress in general) and disease outcomes were described above, including associations with cardiovascular disease, cancer, and metabolic disease. Beyond this, job strain is associated with physical health symptoms and decline that are not explicitly disease outcomes, such as low back pain and general musculoskeletal pains (Amiri & Behnezhad, 2020). Reflective of this, job stress more generally has been associated with a myriad of physical symptoms, including backache, headache, eye strain, sleep disturbance, dizziness, fatigue, dysregulated eating, and gastrointestinal problems (Nixon et al., 2011). Studies have highlighted the link between job strain and negative physical health more broadly, showing job strain to be associated with significantly fewer years of healthy life expectancy and chronic disease-free life expectancy (Hanson et al., 2018). These symptoms and disease outcomes are associated with physical decline and reduced physical capacity. Conversely, in the absence of health risks such as job strain, higher psychological wellbeing is associated with increased physical health and prolonged life (Hernandez et al., 2018).

The associations of job strain with declines in both mental and physical health show the importance of investigating job strain for its deleterious effects on health. However, physical and mental health are closely linked, and declines in one are often associated with declines in the other (Hernandez et al., 2018). Supported by empirical research evidence, the close relationship between mental and physical health has been described as bidirectional (Kivimäki et al., 2020). This outlines another layer of complexity through which job strain may affect mental and physical health, because an association may not occur in isolation but instead flow from one to the other.

The evidence that job strain is related to mental and physical health proffers further, albeit more complex, pathways through which to theorise a relationship with BMI. This is because mental and physical health are associated with BMI and with health behaviours that directly affect BMI. First, physical activity levels are a direct contributor to the energy balance equation. Given this, the negative effect of job strain on capacity to engage in physical activity is more self-evident for its association with increased BMI. A broad body of research has reported that fatigue, disease, and poor health are barriers to physical activity, including LTPA, and are associated with the accrual of a positive energy balance (Bültmann et al., 2002; Pawlikowska et al., 1994; Resnick et al., 2006; Williamson et al., 2005).

Second, there is evidence that declines in mental health and mental health conditions such as depression are associated with increased BMI (Cameron et al., 2012; Luppino et al., 2010). Rates of depression and depressive symptoms are shown to be higher among those with obese BMIs (Atlantis & Baker, 2008; Faith et al., 2011). However, there is agreement that the relationship between depression and obesity is bidirectional, meaning that depression conveys a prospective risk for increasing BMI and obesity, while high BMI also conveys a prospective risk for depression (Rajan & Menon, 2017). In explaining the prospective association of depression with increasing BMI, depression can be associated with reduced

physical activity (Roshanaei-Moghaddam et al., 2009) and disrupted eating (Ouwens et al., 2009), which can create a positive energy balance. Indeed, disrupted eating and altered physical activity levels (i.e., lethargy and fatigue) are reflected in the diagnostic criteria of depression, among others.

1.6.1.3 Summary of This Section

Job strain, BMI, fatigue, and mental and physical health are multifactorial constructs with a high degree of individual variance in the deterministic pathways and presentation. Thus, elaborating the relationships among them is complex. On this, there are inconsistencies and criticisms in the literature. However, the above has summarised general trends in areas of research related to theorising whether an association between job strain and BMI is a possibility. The weight of the evidence suggests that there are various pathways through which a relationship between job strain and BMI may present.

1.7 Summary of Possible Differences by Sex

An important consideration for this thesis is whether an association of job strain with BMI may differ for males and females. This introduction has laid out general evidence for theorising an association of job strain with BMI; however, there are often differences for males and females among this evidence. This section describes differences in patterns of labour force participation by sex, differences in the stress–health relationship, differences in coping with stress by sex, differences in the epidemiology of overweight and obesity, and trends in BMI distribution over time, by sex. Accordingly, an association between job strain and BMI may be different for male and female workers, although given the mixed findings among the studies, it is unclear whether there are differences, and if so, exactly how and what differences to expect.

There are various aspects of work that are commonly accepted as different between males and females. At a broad level, there are gender differences in labour-force participation

statistics: more males work in full-time positions than females, and from an earlier age in life (Gustafsson, 2021; OECD, 2022). Conversely, more females are employed in casual and part-time roles (Black Dog Institute, 2021; Gustafsson, 2021; OECD, 2022). Accordingly, males tend to spend a higher number of weekly hours in paid employment than females (OECD, 2022). On average, females also earn less from paid employment, reducing access to financial resources and stability (Lundberg, 1996; Workplace Gender Equality Agency, 2021).

The way in which paid work is structured within the lives of males and females also differs. While males spend more time in paid employment, females engage in more caretaking and unpaid labour than males (Maume, 2006; Doan et al., 2022; Krantz et al., 2005). This suggests a higher degree of complexity regarding managing responsibilities and role transitions in everyday life for females (Lundberg, 1996; Matthews & Power, 2002). In line with this, epidemiological data show that females report higher levels of general everyday stress, anxiety, and depression (Almeida & Kessler, 1998; Barrington et al., 2014; Leach et al., 2008; Van de Velde et al., 2010). Regarding stress within the working population of females in Australia specifically, data from 2001 to 2017 show that a higher proportion of working females report high or very high psychological stress consistently compared to males (Black Dog Institute, 2021).

Based on these factors, it is possible that job strain is experienced by and affects males and females differently. Consistent with this, data from workers compensation claims show that a higher proportion of females' compensation claims are related to mental stress at work than males (Safe Work Australia, 2019). Only mental stress claims showed a difference by sex; differences by sex were not present among other work compensation claim types. Thus, differences in the experience of work may create the potential for psychosocial stress at work, including job strain, to present differently for males and females. In line with this, data

on population-level exposure patterns from a working sample from Victoria, Australia, showed job strain to be significantly more prevalent for females than males (Keegel et al., 2009). Although more data are needed to reliably gauge sex differences, it is plausible that females experience job strain more often than males.

Further reasons to suspect differences in the association between job strain and BMI include sex differences in patterns of coping behaviourally and emotionally with stress (Barlow, 2004; Griep et al., 2015) in ways that are likely to affect BMI differently. For example, in response to stress, females may engage in more emotion-focused coping than males (Kelly et al., 2008; Matud, 2004; Tamres et al., 2002). Common emotion-focused coping strategies include indulging in eating and drinking, which may influence a positive energy balance (Cortes et al., 2021). This is in combination with other evidence suggesting that females who work are less likely to engage in active LTPA (i.e., exercise) and healthy eating practices (including meal planning and healthful food selections) (Au et al., 2012).

However, sex differences in health behaviours are not clear and consistent (Kivimäki et al., 2006). Some studies have reported that males are more likely to engage in unhealthy eating and drinking as a reaction to stress (Horta Esper & Furtado, 2013; Papier et al., 2015), while others have reported no differences in associations of working characteristics and active LTPA by sex (Fransson et al., 2012). Thus, while many note the potential for sex differences in health behaviours (Block et al., 2009; Griep et al., 2015; Kivimäki et al., 2006), the effect and extent of the possible differences remain unclear.

There is evidence that sex moderates associations between job strain and health indicators related to BMI, such as cardiovascular disease, metabolic syndrome, and diabetes (Kautzky-Willer et al., 2016; Matud, 2004; Pradhan, 2014). For example, differences in the strength of association of work stress and job strain with cardiovascular disease, stroke, and hypertension have been observed between males and females (Huang et al., 2015; Johnson &

Hall, 1988). Consistent with observing these differences, researchers have noted differences by sex in physiological stress responses (Bale & Epperson, 2015; Epel, 2018; Kivimäki et al., 2006).

Finally, there are differences in the epidemiology of overweight and obesity in Australia, and trends in BMI increase over time, between males and females. Globally, data suggest that females are overweight and obese in greater proportions than males (Chen et al., 2019). However, in Australia, more males are classified as overweight or obese compared to females (AIHW, 2017; Vic Health, 2013). Despite this, more females exhibit extreme BMI values compared to males. Trends over time show that females tend to gain weight at a faster rate than males (Haby et al., 2011). Further, evidence suggests that working females may be particularly vulnerable to faster weight gain, demonstrating larger weight increases over time compared to non-employed females (Au et al., 2012).

In summary, while sex differences in the research examining work stress and health, and BMI specifically, support the conceptualisation of a relationship between job strain and health that differs for males and females, the inconsistency in the literature limits our ability to clearly hypothesise or conclude directions for sex differences. The approach taken in this thesis is to stratify investigations by sex to explore potential differences on the basis that further information on these differences would be beneficial to the literature.

1.8 Chapter Summary

The present thesis is an exploration of a potential association between job strain and BMI. Sound theoretical reasons and empirical evidence create a persuasive case for the investigation of whether experiencing job strain is associated with BMI. The theoretical reasons for expecting a relationship with BMI, involving both direct biological stress mechanisms and indirect health behaviours in response to job strain, were explained and discussed in this chapter. Further, the possibility of more diffuse pathways through other

factors associated with job strain and BMI, specifically fatigue and mental and physical health, have been suggested.

A small body of literature has specifically examined the associations of job strain and its component subscales, job demands, and job control, with BMI and BMI-related outcomes such as overweight, obesity, and body weight. These studies are described and reviewed in the introduction of each analysis chapter. There has been little consistency reported in the findings of these studies, providing limited confidence in whether an association exists. However, the inconsistencies also provide an impetus, and denote gaps, for further investigations to clarify the state of the literature. Importantly, the need for an in-depth, comprehensive review (and subsequent investigations) of job strain and BMI is identified, and this then informs the research questions in this thesis.

In the analysis chapters, a critical examination of existing studies suggests that the inconsistent findings may be a result of conceptual and/or analytic differences and limitations. This informs the investigation of the current thesis to conserve the best features of the prior literature while attempting to overcome prior limitations. The more nuanced literature review at the beginning of each analysis chapter aligns the existing literature with the chapter's specific aims and research questions, as well as the analyses undertaken.

1.9 Research Questions and Aims

As outlined above, the specific aims and research questions addressed in this thesis unfold within each analysis chapter, building upon one another to comprehensively explore the possible connection between job strain and BMI. The research questions use four waves of data from a community-based longitudinal study, beginning with cross-sectional analyses and building to longitudinal mixed models, an exploration of the role of baseline BMI, and an investigation of the accumulated experiences of job strain over time. The research questions and aims that are addressed in this thesis are as follows:

1. Is there an association between job strain and BMI?

While this first research question is the broad, overarching question that applies to and is addressed in all of the analyses conducted within this thesis (albeit in different ways), this thesis begins by considering the association cross-sectionally. The first analyses chapter (Chapter 3) reviews the existing evidence for a cross-sectional relationship, and then cross-sectional analyses are conducted to examine whether there is an association in the dataset used in this thesis.

2. Is there an association between job strain and BMI over time?

Initially, the existing literature is critically appraised to develop a more detailed theory and understanding of how a relationship may present over time (Chapter 4). Longitudinal analyses then explore the relationship between work stress and BMI using different models to canvas whether any particular longitudinal model of job strain and BMI over time works best, and whether all models tell a consistent story. The relationship between job strain and BMI over time is represented and tested in four different sets of analyses:

- a) A general random effects model: This model examines job strain in association with BMI levels using a random intercept model.
- b) A fixed-effects model: This model examines changes in job strain in association with changes in BMI over time, excluding time-invariant variables.
- c) A baseline job strain model: This model uses only the baseline job strain score to examine associations with the subsequent BMI score.
- d) A lagged job strain model: This model assesses whether job strain at a prior time point predicted subsequent BMI at the following time point.

Each set of analyses has different advantages and a different focus on the association longitudinally (as explained in more detail within the relevant chapter).

3. Is an association of job strain and BMI over time moderated by the individual's baseline (i.e., initial) BMI?

The aim of this research question is to examine whether where individuals begin on BMI (their initial BMI at baseline) interacts with job strain to change their BMI level differently from those who never experienced job strain (Chapter 5).

4. Is there a cumulative effect of job strain on BMI over time?

This question aims to investigate whether there is evidence of a dose-response, or other cumulative, relationship between increasing counts of job strain over 12 years and BMI at follow-up (Chapter 6). There is again an exploration of the role of baseline BMI—that is, whether a relationship between the accumulation of job strain on BMI over time is moderated by baseline BMI.

A further broad aim that cuts across each chapter is the investigation of differences in these research questions by sex. The available evidence suggests that associations of job strain and BMI may differ depending on sex (discussed within the analyses chapters). Given this, and similar to the practices of some prior studies, the analyses throughout this thesis have been stratified by sex. Stratification and separation of results provides an opportunity to compare and contrast potential differences by sex.

Last, this thesis aims to contribute new information and insights on what is known about job strain and BMI in Australia. Consideration of the potential for an association of job strain with BMI is important and valuable research. This importance is highlighted by the increasing prevalence of obesity and overweight and the corresponding increase in average BMI and the rightward shift of the population BMI distribution. This is in combination with the increasing costs and effects of job strain at various levels, including on the economy and for businesses, for individuals' health and wellbeing, and in relation to the burden of disease that is associated with job strain. This is the case in Australia and globally. This thesis is the

first to examine longitudinal Australian data on job strain and BMI over time. This thesis makes a valuable contribution by providing insights into the state of the relationship between job strain and BMI in Australia, if any. In addition to identifying and attempting to overcome the limitations of past research, this thesis aims to contribute new explorations, both theoretically and analytically, by examining the association between job strain and BMI within the Australian population.

Chapter 2: Methodology

2.1 Chapter Summary

This chapter contains detailed information about the PATH Through Life study and the survey data obtained in the study. Data collection methods are described, along with the scale and variable construction and coding (with a focus on the key variables critical to this thesis: job strain and BMI), important scale characteristics, and the data analysis techniques employed in this thesis. The study sample is described in relation to both job strain and BMI, as well as important covariates.

The PATH Through Life study surveyed three cohorts aged in their 20s, 40s, and 60s at baseline data collection. This thesis focuses on the 40s cohort who provided data on job characteristics at every wave (because only the 40s cohort was measured at every wave on key work variables relevant to this thesis with minimal attrition). This thesis is strengthened by the opportunity to include and analyse data from the first four waves of the PATH 40s cohort, corresponding to 12 years of follow-up data on the study participants. While an awareness of the 60s cohort is integral to understanding the planned structure and overall aims of the PATH study, job characteristics were not measured in this cohort.

The 20s cohort, along with the 40s cohort, is included in the cross-sectional analyses in Chapter 3 (analysing data from wave two, when work variables were first measured from the 20s cohort). There were two main reasons for including the 20s cohort in the cross-sectional analyses only: first, work variables were not measured for the 20s cohort at wave one; and second, there was substantial attrition at wave three and especially at wave four for the 20s cohort. Thus, it was decided that the addition of the 20s cohort was beneficial for the cross-sectional analyses of wave two data, but that there were significant limitations in using the 20s cohort in the longitudinal modelling. Accordingly, the 20s sample is described in the following cross-sectional analyses chapter (Chapter 3), while the current chapter largely

focuses on the 40s cohort, which is the sample featured consistently throughout all analyses within the current thesis.

All features of the methodology that are consistent across every analysis within this thesis are described in this chapter, while any part of the methodology that was adapted or is different and applicable to a particular chapter is described in detail within that chapter. The varying statistical methods and models used in each chapter are described here to provide an understanding of the thesis program as a whole (with further detail provided in the relevant chapters).

2.2 Data Collection Process

2.2.1 PATH Through Life Survey Purpose and Overview

The data used in the current thesis were drawn from the PATH Through Life survey project, a longitudinal community-based survey set in Australia. Beginning in 1999, the PATH survey project followed three differing age cohorts—those in their 20s, 40s, and 60s—and collected five waves of data approximately every four years, over a 20-year period (four waves of data had been collected at the time this thesis began, and the fifth wave was collected subsequently). The purpose of the PATH study was to provide a rich dataset through which life-course information could be analysed to assess risk and protective factors for mental health, cognitive functioning, and healthy ageing across varying age groups. Detailed information on the PATH Through Life survey project methods and participants has been published elsewhere (i.e., Anstey et al., 2020, 2012), and these published papers have informed the detail in this methods chapter.

2.2.2 PATH Through Life Study Participants

The PATH Through Life survey sampled participants from the Canberra and Queanbeyan regions of Australia (Australian Capital Territory [ACT] and New South Wales [NSW], respectively). The PATH study recruited three cohorts of individuals: a group of participants initially aged 20–24 years, a group initially aged 40–44 years, and a group initially aged 60–64 years at baseline. Baseline data collection for wave one of the 20s cohort began in 1999, data collection for wave one of the 40s cohort began in 2000, and data collection for wave one of the 60s cohort began in 2002.

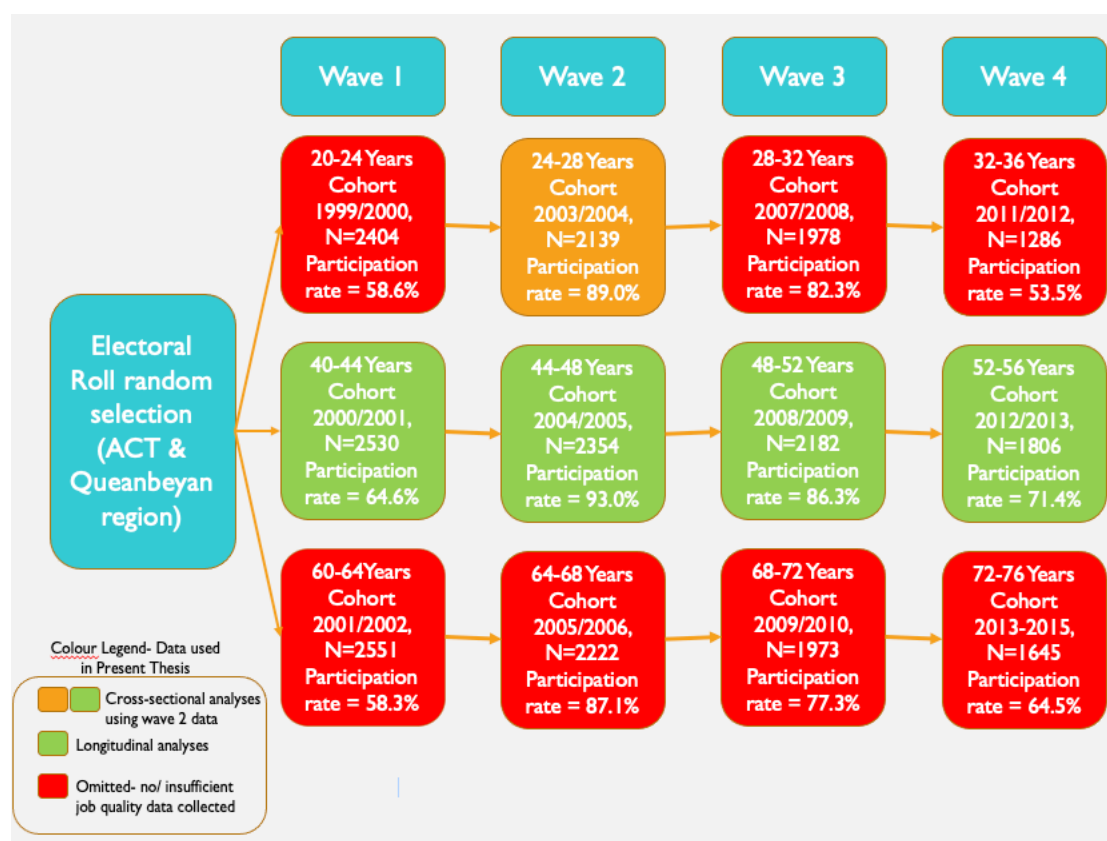
Participants were randomly selected from the ACT and Queanbeyan electoral rolls to be invited to participate (registration on the electoral roll is compulsory for all Australian citizens aged 18 and over). Age cohorts on the electoral role were not sensitive enough to target the specific age range determined for the PATH study. Thus, to recruit participants aged 20–24 and 40–44 years old, a letter was sent to 12,414 and 9,033 people listed as aged 20–29 and 40–49 respectively, who were registered on the electoral roll. This resulted in an initial recruitment of 1,163 males and 1,241 females for the 20s cohort (58.6% participation rate) and 1,193 males and 1,337 females for the 40s cohort (64.4% participation rate). The participation rate reflects only those individuals from the electoral roll in the correct age range for the PATH study criteria. Every four years, participants were asked again whether they wanted to participate in each subsequent wave of the study. Table 2.1 and Figure 2.1 show the year that each wave of data collection began, as well as the participation (at wave one) and retention rates (at subsequent waves) for the 20s and 40s cohorts.

Table 2.1*PATH Cohort Data Collection Years, Sample Size and Retention Rates*

Cohort	Wave	Year	N	Participation/Retention
20s	1	1999/2000	2,404	58.60%
	2	2003/04	2,139	89.00%
	3	2007/08	1,978	82.30%
	4	2011/12	1,286	53.50%
40s	1	2000/2001	2,530	64.60%
	2	2004/05	2,354	93.00%
	3	2008/09	2,182	86.30%
	4	2012/13	1,806	71.40%

Figure 2.1

Structure of Data Collection for the PATH Through Life Survey, Including Attrition and Participation Rates for Each Wave by Age Cohort



Note. Adapted from Anstey et al. (2020).

2.2.3 Procedure at Each Wave

At wave one, persons randomly selected from the ACT and Queanbeyan electoral rolls were sent information about the study and an invitation to participate by mail (see Appendix A). Individuals who consented to participate were contacted by a trained interviewer to arrange a time and place to meet (usually the participant's home or the Centre for Mental Health Research at the Australian National University [ANU]). Each interview took approximately 90–120 minutes to complete, with the interviewer demonstrating how to answer the self-reported survey questions on a handheld device (a Hewlett Packard palmtop pc 620LX) using Surveycraft software. The participants completed most of the interview alone (without intervention from the interviewer), including the job quality, height, and weight questions. This maintained the confidentiality of participants' responses, which has been shown by past research to boost the accuracy of the data obtained through minimising socially desirable responses.

At subsequent waves of data collection, the interview procedure was maintained as consistently as possible. For the first three waves of data collection, trained interviewers were present for data collection similar to wave one; however, at wave four, a large proportion of participants completed the survey interview online, without a trained interviewer present. At wave four, the participants were recontacted by phone and, upon consenting to participate, they were provided with a unique login and access to the online survey. Other participation options were also available at earlier waves when participants had moved overseas or out of the area, or for any other reason they could not complete the interview in person (e.g., by mail, email, or over the phone).

Attrition poses a significant challenge to longitudinal studies because it reduces the power and strength of modelling and analyses, creating confounds to be considered when interpreting the data (Teague et al., 2018). To minimise attrition within the PATH study, a

combination of follow-up, reminder, and tracing strategies was used, including sending an annual Christmas card and a newsletter that included reply paid 'change of address' notifications, and encouraging participants to maintain up-to-date name, address, phone, and email contact details. Further, each participant was asked to provide the contact details of two people who they consented could be contacted if the participant could not be reached directly. In the event that both contacts could not be reached, updated addresses were obtained via the Australian electoral roll, and the electronic White Pages directory was searched for updated contact information.

2.2.4 Ethics

The PATH Through Life project complies with the National Medical Health and Research Council (NHMRC) guidelines for ethical practice in research. Participants provided informed consent with the understanding that participation was voluntary and that they could decline to answer any or all questions, or withdraw consent to participate at any time. Protocol (No. M9807) for wave one of the PATH study was approved by the ANU Human Research Ethics Committee (HREC) on 22 September 1998. Protocol (No. 2002/189) for wave two of the PATH study was approved by the ANU HREC on 11 November 2002. Protocol (No. 2006/314) for wave three of the PATH study was approved by the ANU HREC on 21 December 2006. Protocol (No. 2010/542) for wave four of the PATH study was approved by the ANU HREC on 4 March 2010. Copies of the ethics approval certificates from the ANU HREC are included in Appendix B.

2.2.5 Inclusion Criteria and Descriptive Statistics for the 40s Cohort

Of the 2,530 participants in the 40s cohort at baseline, 1,193 were male (47.15%) and 1,337 were female (52.85%). The inclusion criteria for the analyses in this thesis required that participants were working full or part time at any wave, which was indicated by a positive status of 'Employed full-time', 'Employed part-time, looking for full-time work', or

‘Employed part-time’ in the PATH data responses (as opposed to being ‘Unemployed’ or ‘Not in the labour force’) and had information on the job strain survey items. These criteria were based on employment and job strain item responses at ‘any wave’ to maximise the number of observations available in the longitudinal analyses (for the cross-sectional analyses conducted in Chapter 3, it was necessary for participants to be employed at that wave). This left 1,130 males and 1,141 females who were eligible for inclusion in the analyses at wave one, 1,030 males and 1,076 females at wave two, 976 males and 1,021 females at wave three, and 700 males and 745 females at wave four. Most of the observations that were excluded were because participants were either unemployed or not in the labour force. Some participants were excluded due to item-missing data on the job strain questionnaire items (a maximum of 11 people at each wave were excluded in either the male or female groups). In addition, females were excluded on a wave-by-wave basis if they responded ‘yes’ to being pregnant in the past 12 months (given the effect of pregnancy on the calculation of BMI). Given the mid-life age of the 40s cohort, pregnancy was not a major confounding variable, with five female participants reporting being pregnant at wave one, and one at wave two. Although the descriptive statistics presented below were unchanged at the third decimal point with the exclusion of pregnant persons, the scores of these individuals were filtered out of the analyses in the thesis. No pregnancies were reported at waves three and four.

Tables 2.2 and 2.3 show the descriptive statistics for the key categorical and continuous variables used in this thesis (further details of these measures and how the variables were constructed are provided in the subsequent measures section). The sample consists of eligible participants at each wave (employed males and females in the 40s age cohort with information on the job strain items), and information on response and missing data is given for each key variable. Table 2.3 shows that the means and standard deviations for the job demands and control scales, and for the job decision authority and skill discretion

subscales, were consistent from wave to wave for each sex. At wave one (baseline), the average person was overweight, with an average BMI of above 25 for males and females. For males, the average BMI increased by 0.88 BMI units across the first 12 years of the PATH study data analysed in this thesis. However, the increase in females' BMI was double that of males from wave to wave (see Figure 2.2), increasing by 1.62 BMI units across the study (from baseline to wave four).

As data collection for the 40s cohort began in their mid-life, years of education for males and females at baseline was over 14 years on average. The proportion of males employed in full-time work (v. part-time) was consistently high, as was the average hours worked per week. The highest proportion of males reporting job strain occurred at wave one, with the smallest proportion reporting job strain at wave four. The majority of male participants reported having children, and declines over time were observed in both the proportions of males reporting current smoking and those experiencing financial difficulty. The proportion of males engaging in weekly exercise remained quite stable. Mental health was lowest for male participants at wave two and highest at wave three, while the lowest average physical health was reported at wave four and the highest at baseline.

Consistent with research showing that females have greater household and care-related obligations that affect their working capacity (Baxter et al., 2012; Offer & Schneider, 2011; Powell & Craig, 2015), the proportion of females employed in full-time work (v. part-time) varied from wave to wave, with the highest proportion reported at wave three. This corresponded to the highest average work hours reported for female participants across the study. The proportion of female participants reporting job strain also varied from wave to wave, with the highest proportions reported at waves one and four. The majority of female participants had children, and declines were observed in both the proportion of those reporting current smoking and those experiencing financial difficulty over time. Proportions

of females engaged in weekly exercise hours were observed to vary somewhat from wave to wave. A consistent increase in average mental health was observed from baseline to wave four, while a consistent decrease was observed for average physical health.

Missing data on BMI were noted across most waves, because there were missing data on height and weight to various degrees at each wave. Height and weight, used to calculate BMI, were self-reported, and it is possible that some participants did not know, or want to disclose accurately, their height or weight (Burke & Carman, 2017; Larson, 2000; Lassale et al., 2013; Peters et al., 2011; Ziebland et al., 1996). For all other covariates, there were minimal missing data, except for two variables (see Table 2.2). The exercise variable had considerable missing data that varied across waves and sex between 0.1% to 12.1% (the latter for males at wave four). There were also substantial missing data for the financial problems question at wave one (16.5% for males and 23.1% for females) because an error in the online survey meant that a substantial number of participants skipped this question. Imputation for missing data was considered in each chapter/analysis in this thesis; however, in each case it was decided not to impute data for the following reasons (Hughes et al., 2019). In Chapter 3, where cross-sectional analyses were undertaken, less than 3% of data were missing for each variable (except for BMI, with 7.6% missing for females, but because this was the main outcome variable data were not imputed). In Chapter 4, where longitudinal data were used, the analyses minimised the effect of the missing data by including all observations where data were available (so participants with missing financial hardship data at wave one would have had their observations in subsequent waves included). Finally, in Chapter 6, where the accumulated effect of job strain was considered over time, covariates were taken from wave four (when there were minimal data missing on financial problems, although considerable data were missing for the exercise variable for males [i.e., 12.1%]).

Table 2.2*Descriptive Statistics for Categorical Variables for the 40s Cohort at Each Wave*

Males													
		W1			W2			W3			W4		
Variable		N=1,130	%	Miss	N=1,030	%	Miss	N=976	%	Miss	N=700	%	Miss
Job strain	Yes	239	21.15	0.00	151	14.67	0.00	155	15.90	0.00	97	13.94	0.00
Employ	F/T	1,063	94.07	0.00	980	95.14	0.00	920	94.26	0.00	627	88.43	0.00
Children	Yes	946	83.72	0.00	870	84.63	0.19	843	86.46	0.10	608	88.50	1.83
Smoke	Yes	220	19.47	0.00	166	16.13	0.10	130	13.36	0.31	59	8.58	1.83
Exercise	Low	293	27.46	5.57	251	24.75	1.55	287	29.56	0.10	172	27.96	12.12
	Mod	418	39.18		439	43.29		384	39.55		257	40.60	
	High	356	33.36		324	31.95		300	30.90		204	32.23	
Finance problems	Yes	227	24.00	16.46	168	16.33	0.10	154	15.79	0.10	89	12.79	1.83
Females													
		W1			W2			W3			W4		
Variable		N=1,141	%	Miss	N=1,076	%	Miss	N=1,021	%	Miss	N=745	%	Miss
Job strain	Yes	278	24.36	0.00	200	18.58	0.00	109	10.68	0.00	152	20.40	0.00
Employ	F/T	705	61.79	0.00	724	67.28	0.00	730	71.49	0.00	522	70.06	0.00
Children	Yes	1,002	87.81	0.00	957	89.52	0.65	912	89.49	0.20	678	92.49	1.58
Smoke	Yes	204	17.87	0.00	173	16.18	0.65	132	12.92	0.39	67	9.15	1.71
Exercise	Low	479	45.27	7.19	412	39.16	2.22	461	45.50	0.87	267	49.25	3.03
	Mod	394	37.24		459	43.63		363	35.80		232	32.08	
	High	186	17.58		186	17.68		190	18.74		135	18.67	
Finance problems	Yes	200	22.73	23.15	213	19.98	0.93	171	16.75	0.20	95	12.96	1.58

Note. The % provided shows the proportion of participants in each category for those who had data available (i.e., the denominator excludes those with missing data).

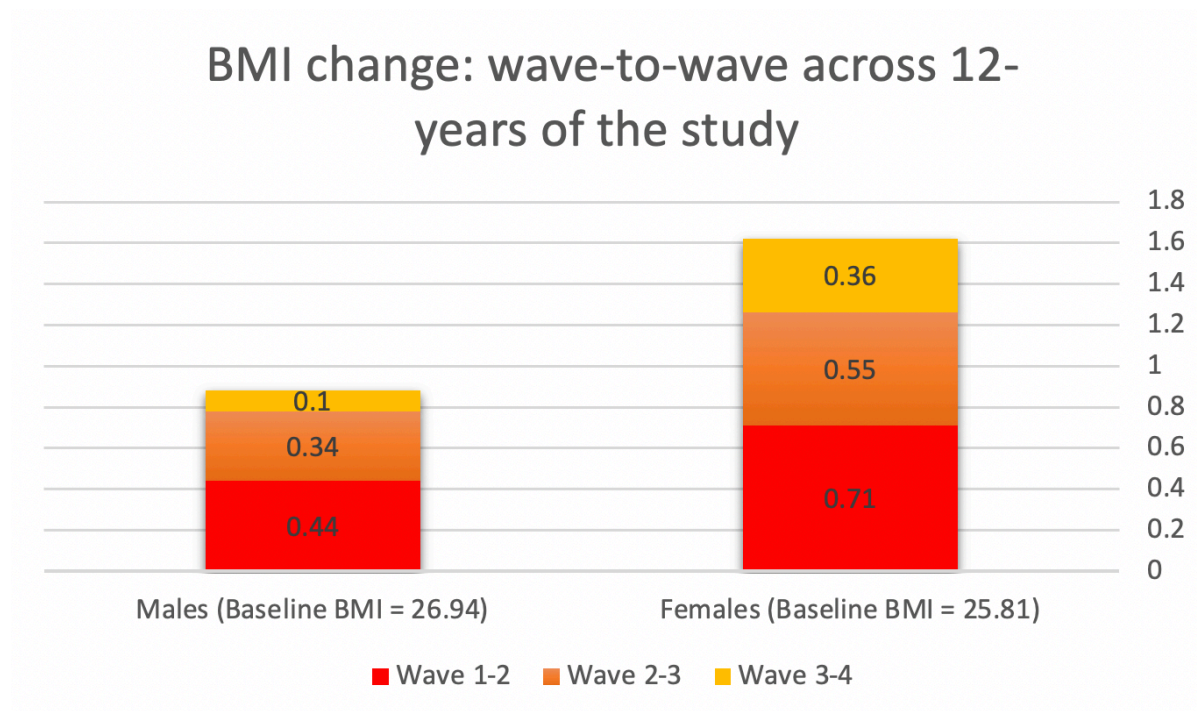
Table 2.3*Descriptive Statistics for Continuous Variables for the 40s Cohort at Each Wave*

Males													
Variable	Range*	W1			W2			W3			W4		
		N=1,130	M (SD)	Miss	N=1,030	M (SD)	Miss	N=976	M (SD)	Miss	N=700	M (SD)	Miss
Job control	7.5–30	1,130	24.31 (3.08)	0.00	1,030	24.56 (3.10)	0.00	976	24.55 (3.10)	0.00	700	24.25 (3.43)	0.00
Job demands	4–16	1,130	11.69 (2.06)	0.00	1,030	11.45 (2.08)	0.00	976	11.35 (2.09)	0.00	700	11.02 (2.19)	0.00
Job skill	6–24	1,130	19.39 (2.63)	0.00	1,030	19.59 (2.59)	0.00	976	19.44 (2.64)	0.00	700	19.24 (2.81)	0.00
Job dec	9–36	1,130	29.23 (4.49)	0.00	1,030	29.53 (4.51)	0.00	976	29.66 (4.55)	0.00	700	29.26 (4.94)	0.00
BMI	18.5–50	1,040	26.94 (4.49)	7.96	981	27.38 (4.26)	4.75	970	27.72 (4.43)	0.61	684	27.82 (4.12)	2.28
Education (years)	9–18	1,052	14.89 (2.19)	6.90	1,029	14.89 (2.19)	0.10	958	14.97 (2.16)	1.84	682	14.98 (2.17)	2.57
Work hours	1–125	1,128	47.09 (12.30)	0.18	1,020	46.98 (8.51)	0.97	973	45.61 (11.43)	0.31	694	43.87 (11.77)	0.85
Rand-MHC	0–100	1,129	50.22 (8.88)	0.09	1,016	49.98 (8.51)	1.35	974	50.65 (8.66)	0.20	692	50.00 (9.17)	1.14
Rand-PHC	0–100	1,130	51.88 (7.02)	0.00	1,008	51.55 (6.93)	2.13	975	51.17 (7.06)	0.10	694	50.69 (7.82)	0.85
Females													
Variable	Range	W1			W2			W3			W4		
		N=1,141	M (SD)	Miss	N=1,076	M (SD)	Miss	N=1,021	M (SD)	Miss	N=745	M (SD)	Miss
Job control	7.5–30	1,141	23.03 (3.67)	0.00	1,076	23.22 (3.66)	0.00	1,021	23.40 (3.34)	0.00	745	22.94 (3.64)	0.00
Job demands	4–16	1,141	11.23 (2.28)	0.00	1,076	11.05 (2.23)	0.00	1,021	11.24 (2.23)	0.00	745	10.94 (2.33)	0.00
Job skill	6–24	1,141	18.65 (3.13)	0.00	1,076	18.93 (3.17)	0.00	1,021	18.93 (2.94)	0.00	745	18.84 (3.07)	0.00
Job dec	9–36	1,141	27.42 (5.42)	0.00	1,076	27.51 (5.39)	0.00	1,021	27.88 (5.12)	0.00	745	27.04 (5.57)	0.00
BMI	18.5–50	1,041	25.81 (5.45)	8.76	999	26.52 (5.59)	7.16	1,010	27.07 (5.56)	1.07	711	27.43 (5.74)	4.56
Education (years)	9–18	1,076	14.58 (2.17)	5.69	1,073	14.53 (2.17)	0.28	1,010	14.59 (2.18)	1.07	739	14.59 (2.17)	0.80
Work hours	1–120	1,136	35.82 (13.94)	0.43	1,066	37.98 (14.83)	0.93	1,010	38.29 (12.76)	1.07	742	37.46 (13.17)	0.40
Rand-MHC	0–100	1,140	48.42 (9.42)	0.09	1,066	49.02 (9.29)	0.93	1,019	49.27 (9.19)	0.19	745	49.76 (8.82)	0
Rand-PHC	0–100	1,141	50.99 (7.91)	0.00	1,060	50.96 (7.84)	1.48	1,018	50.04 (8.26)	0.29	744	49.75 (8.71)	0.13

Note. * Range is possible values, except for education and work hours, where the lower and upper bounds are indicated by actual data values.

Figure 2.2

Average Difference in BMI from Wave to Wave of the PATH Study, by Sex



Note. The average change is represented in BMI units (vertical axis). Zero on the vertical axis represents BMI at baseline, which differed for males and females.

2.2.6 Differences in the Sample Between Those with Complete and Incomplete Data

It was important to consider whether those who dropped out of the study might be different to those with complete data across all waves. Tables 2.4 and 2.5 present descriptions and tests of the differences in baseline characteristics between participants with complete data (completers) for all waves on job strain and BMI at waves one and four, compared with participants who were missing on these variables at any wave (non-completers). At baseline, male non-completers were more likely to have job strain, be smokers, not have children, and have worse mental and physical health compared with male completers. Female non-completers were more likely to have reported smoking at baseline, not have children, have worse physical health, and to have experienced financial difficulty compared with female completers. These findings suggest that some characteristics are different between those with

complete data and those without. In particular, the higher job strain in male non-completers may lead to an underestimation of the effect of job strain depending on the particular analyses undertaken. This is particularly relevant to Chapter 6, where the analyses include only those with job strain data across all four waves and data on BMI at wave four (this is further explained in the relevant chapter). There were no significant differences in BMI at baseline between completers and non-completers.

Table 2.4

Categorical Descriptive Variables at Wave One for Those Who Dropped Out at Any Wave (Non-Completers) v. Were a Complete Case (Completers)

		Males			Females				
Baseline variable		Non-completers %	Completers %	P	N	Non-completers %	Completers %	P	N
Job strain	No	51.74	48.26		891	58.78	41.22		866
	Yes	59.41	40.59	.035	239	60.43	39.57	.625	278
Children	Yes	51.48	48.52		946	57.49	42.51		1002
	No	63.04	36.96	.004	184	71.33	28.67	.002	143
Smoking	No	50.66	49.34		910	57.28	42.72		941
	Yes	64.55	35.45	<.001	220	68.14	31.86	.004	204
Exercise	0	53.58	46.42		293	60.96	39.04		479
	1	53.59	46.41		418	58.38	41.62		394
	2	52.01	47.99	.348	356	53.23	46.77	.190	186
Finance problems	No	49.65	50.35		732	55.59	44.41		680
	Yes	54.19	45.81	.234	241	68.50	31.50	<.001	200

Table 2.5

Continuous Descriptive Variables at Wave One for Those Who Dropped Out at Any Wave v. Were a Complete Case (Completers)

	Males					Females				
	Non-completers	N	Completer	N	P	Non-completers	N	Complete	N	P
Continuous	M(SD)		M(SD)			M(SD)		M(SD)		
Baseline BMI	27.01 (4.75)	519	26.87 (4.21)	525	.604	25.99 (5.43)	582	25.59 (5.47)	464	0.247
Rand MHC	49.70 (9.54)	602	50.81 (8.02)	525	.035	48.03 (9.49)	678	48.98 (8.59)	464	0.092
Rand PHC	50.26 (7.76)	603	52.58 (5.99)	525	.001	50.31 (8.41)	678	51.98 (7.01)	464	<.001
Years of education	14.79 (2.20)	525	14.99 (2.17)	525	.151	14.49 (2.18)	609	14.71 (2.16)	464	0.098
Job hours	46.71 (12.63)	601	47.52 (11.90)	525	.267	35.39 (14.43)	671	36.43 (13.21)	464	0.219

2.3 Measures and Variables

This section details each measure used in the analyses in this thesis, including examples of the initial survey/questionnaire items, how items were coded for analysis, and any important psychometric properties of scales. All of the variables described varied over time except for education, which was recorded at wave two.

2.3.1 Employment, Job Quality, and Overweight and Obesity Measures

2.3.1.1 *Employment Status*

Participants were asked about their employment status at each wave of data collection and responded whether they were: 1) employed full-time, 2) part-time looking for full-time work, 3) employed part-time, 4) unemployed and looking for work, or 5) not in the labour force. Table 2.6 presents data on employment status wave by wave for males and females, where those who responded 1 were classified as full-time, those who responded 2 or 3 were classified as part-time, and those who responded 4 or 5 were excluded. Because participants could exit or re-enter the workforce during any wave, their observations/data were excluded from analyses using an employment filter for any wave for which they reported they were not full- or part-time employed (because they did not report job strain data).

Table 2.6

Employment Status Per Wave for Males and Females

Wave	Full-time	Part-time	Excluded	Total
Males	%	%	%	N
1	89.18	5.63	5.20	1,192
2	88.93	5.54	6.54	1,102
3	88.97	5.42	5.61	1,034
4	75.00	9.81	15.19	836
Females				
1	52.77	32.93	14.30	1,336
2	57.92	28.56	13.52	1,250
3	63.76	25.59	10.66	1,145
4	53.87	24.26	21.88	969

2.3.1.1.1 Job Demands and Control, Skill Discretion, and Decision Authority

The items comprising the job demands and control scales at each wave were taken from the Whitehall study, which was modelled on the Job Content Questionnaire (Bosma et al., 1997; Karasek et al., 1998). Job demands were measured using four items asking questions such as ‘Do you have to work very fast?’ Skill discretion was measured using six items asking questions such as ‘Is your job boring?’ Decision authority was measured using nine items asking participants to indicate how often they experienced choices such as ‘I have a great deal of say in planning my work environment’ and ‘Others take decisions concerning my work’. Each item had four response options: ‘1 = Often, 2 = Sometimes, 3 = Rarely, and 4 = Never’. A total job demands score was calculated by summing all of the item responses. The score was then calculated by averaging the total of the decision authority and skill discretion subscale items. Scores on the job demands and control scales were then split at the median to create dichotomised high and low job control and high and low job demands categories, where 0 represented high (scores above median scores) and 1 represented low (scores below median scores). The median value used was wave specific; however, upon inspection, the wave medians were largely comparable across waves (see Table 2.7). Cronbach’s alphas were computed for the job demands and control scales by wave, as shown in Table 2.7.

Table 2.7

Median and Cronbach’s Alphas for Job Strain Component Scales Per Wave

Wave	Job strain component scales	Median value	Cronbach’s alpha
1	Job demands	11	.70
	Job control	24.5	.91
2	Job demands	11	.65
	Job control	24	.86
3	Job demands	11	.68
	Job control	24.5	.85
4	Job demands	11	.69
	Job control	24	.86

2.3.1.1.2 Job Strain

Job strain, originally derived from Karasek's job demands and control theory of work stress (Karasek, 1979), was selected for analysis because it is a combined measure of job control and job demands and is the most widely studied measure of work stress. Participants responded to the job demands and job control Likert-scale questions described above, and the high/low median splits were derived as explained. Following this, a job strain variable was coded: the high job strain category (coded as 1) was indicated when participants/scores demonstrated a combination of low job control and high job demands, and a no-strain category (all other job types, coded as 0) was indicated in the absence of this combination.

2.3.1.1.3 BMI

Participants self-reported their weight to the nearest kilogram at every wave. However, they only self-reported their height at waves one and two, to the nearest centimetre or foot and inch. Wave one height was selected for the calculation of participants' BMI because it had a higher responsiveness than wave two; however, if wave one data were missing, wave two data were used instead, if present. Participants' BMI was calculated using their weight in kilograms divided by their height in metres squared (weight [kg]/height [m²]). Participants with BMI less than 18.5, classified as underweight according to the WHO (2000) standards, were excluded from the analyses (25 participants at wave one, 16 participants at wave two, 12 participants at wave three, and 11 participants at wave four). However, these participants were not permanently dropped from the dataset because their BMI was able to increase above 18.5 variably across waves. Tracking these individuals showed that 13 had a BMI lower than 18.5 at two waves, and only one individual had a BMI lower than 18.5 at three waves of data. In line with similar studies (e.g., Nyberg et al., 2012; Ostry et al., 2006; Paige et al., 2014), six female (three observations at wave one, two at wave two, and one at wave three) and 12 male (six observations at wave one, three at wave two, and three at wave

three) participants' observations of BMI greater than 50 were also removed from analyses variably across waves, because prior literature shows a greater measurement error in the extremes of BMI, especially with self-report methods (Preston et al., 2015; Stommel & Schoenborn, 2010).

2.3.2 Covariates

Prior research suggests that is important to account for variables that may confound an association of job strain with BMI (Solovieva et al., 2013). In research on BMI, it is standard practice to use a number of control variables such as those selected in this thesis (Azagba & Sharaf, 2012). In line with this, a range of covariates was included in the analyses to control for the possible confounding of the association between job strain and BMI. The selection of covariates was also influenced by the available variables measured within the PATH Through Life study.

Broad evidence agrees that socioeconomic circumstances affect health (Galobardes et al., 2007; Kivimäki et al., 2020), and that there is a social gradient in BMI that is particularly evident for obesity prevalence, but also for overweight (Markwick et al., 2013; Wamala et al., 1997). Broadly, work characteristics also contribute to the social gradient observed in health (Clougherty et al., 2010). There are many indicators of SES, of which occupational status is one commonly used indicator. Other common indicators include education and financial position (Galobardes et al., 2007). Education is positively correlated with indicators of higher SES, and along with socioeconomic position, is negatively associated with BMI (Hayes et al., 2019). Financial hardship has previously been used as a financial indicator of SES (ABS, 2002; Butterworth et al., 2009). Given the heterogeneity of the relationship between SES and health outcomes such as BMI, previous research has advised to control for these relationships using a range of indicators in epidemiological research (Galobardes et al., 2007).

Other important covariates, including mental and physical health, are broad indicators of health and therefore important to control for (and given their associations with both job strain and BMI) (Hernandez et al., 2018; Kivimäki et al., 2020; WHO, 2020). Smoking is associated with BMI such that current smoking reduces BMI (Filozof et al., 2004; Piirtola et al., 2018). Exercise is strongly associated with BMI: those who report higher levels of weekly exercise, and higher-intensity exercise, are likely to have lower BMI (AIHW, 2017, 2021; Waller et al., 2008). There is evidence that becoming a parent is a life event that is associated with increased BMI, particularly among mothers (Corder et al., 2020; Laroche et al., 2013). Having children can be associated with BMI through exposure to more snack foods and more complex family obligations and caring duties, which may leave less time for exercise (Janghorbani et al., 2008; Laroche et al., 2013). Finally, there is empirical evidence that working longer hours is associated with increased BMI gain over time, which has been supported in a recent meta-analysis and systematic review of studies (Au et al., 2013; Solovieva et al., 2013; Zhu et al., 2020).

The covariates selected for inclusion were also closely aligned with previous similar investigations of job strain and BMI (e.g., Azagba & Sharaf, 2012; Solovieva et al., 2013). Many of the relationships of these variables with job strain and BMI were described in detail in the introductory chapter. For a comprehensive approach, and for comparison with other prior literature, the estimates for each of the covariates was reported in all analyses throughout this thesis. However, the covariate estimates cannot be interpreted as total-effect estimates. Interpreting the covariate estimates in this manner (as a total-effect estimate), as job strain should be (as it is the primary variable under investigation) may lead to misinterpretation. It is not the intention of this thesis to report the covariate effects for interpretation as secondary exposures, or secondary variables of investigation (Westreich &

Greenland, 2013; Bandoli et al., 2018). Each measure used for the covariates and its operationalisation is described below.

2.3.2.1.1 Physical and Mental Health

Self-rated physical and mental health were assessed at each wave using the 12-item Short-Form Health Survey (SF-12), which is a summary version of the larger 36-item Short-Form Health Survey (Ware et al., 1996). The SF-12 has shown good reliability and validity in longitudinal research (Gill et al., 2007; Jenkinson et al., 1997; Ware et al., 1996). The SF-12 is composed of two components: the Physical Health Component (PHC) and the Mental Health Component (MHC). Using the RAND-12 scoring method that has been validated for use in community-based population studies (Windsor et al., 2006), six physical health items were scored to calculate the PHC, and six mental health items were used to calculate the MHC (Ware et al., 1996). The possible range of these scales was 0–100, and Cronbach's alphas for the PHC (Cronbach's alphas = 0.72, 0.72, 0.74, and 0.78 at each wave respectively) and MHC (Cronbach's alphas = 0.79, 0.78, 0.78, and 0.80 at each wave respectively) demonstrated good internal consistency at each wave of data collection. Items included, 'In general, would you say your health is ...' and 'During the past four weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?' Participants' scores for each scale were then entered continuously into each analysis.

2.3.2.1.2 Education

A measure of years of education was included as a covariate in all fully adjusted models. Education was measured most comprehensively at wave two of the PATH study and, given that education changes little during mid-life on average, the wave two 'years of education' variable was used throughout all analyses (i.e., this variable did not vary over time). In Canberra, the education profile of ACT residents is quite high compared to the rest

of the country, reflecting the higher-than-average SES profile (ABS, 2016). Accordingly, both the sample mean (see Table 2.3) and median (16 years) were quite high. Education was maintained continuously in the analyses after the inclusion of a categorical education variable demonstrated no notable differences to the model.

2.3.2.1.3 Work Hours

The number of hours that participants worked in a routine week, including unpaid overtime and work taken home, was recorded at each wave. An upper limit of 125 hours worked per week was decided a priori for the dataset, corresponding to an approximate maximum 18-hour working day over a seven-day week. However, the maximum number of work hours reported across the four waves of data collection was 120 for females and 125 for males; thus, no top-coding was required. While this upper limit may appear extreme, it corresponds to plausible working hours and is in line with capturing the theorised reality of those experiencing work strain (i.e., Virtanen et al., 2020). There were no notable differences in estimates from models with work hours entered as a continuous or categorical variable, so working hours was included as a continuous variable throughout this thesis.

2.3.2.1.4 Exercise

At each wave, participants were assigned to one of three categories depending on the intensity and number of hours of exercise they reported per week, corresponding to high, moderate, or low amounts of exercise and its intensity. This was based on the Whitehall study exercise categories (Department of Epidemiology & Public Health, 1991), in which those reporting more than 1.5 hours of vigorous exercise per week were coded as group 2, indicating high amounts and/or intensity of exercise, those reporting more than 1.5 hours per week of moderate exercise, but less than 1.5 hours per week of vigorous exercise, were coded as group 1, indicating moderate amounts and/or intensity of exercise, and those reporting less

than 1.5 hours of moderate exercise were coded as group 0, indicating low amounts of exercise and intensity.

2.3.2.1.5 Smoking

A question about current smoking was asked at each wave of data collection and was adjusted for in all analyses. Participants responded to the question ‘Do you currently smoke?’ with ‘Yes’ or ‘No’. The responses were then coded into two groups (1 = ‘Yes, currently smoking’ and 0 = ‘Not currently smoking’).

2.3.2.1.6 Children

Whether participants had children or not at each wave was coded into one of two groups following their ‘Yes’ or ‘No’ response to the question ‘Do you have any children?’ (0 = ‘No children’ and 1 = ‘Yes, children’). A positive ‘Yes’ response was inclusive of children who were adopted, stepchildren, and children not currently living with the participant.

2.3.2.1.7 Financial Hardship

A binary financial hardship indicator was created for each wave where 0 represented no financial hardship and 1 represented financial hardship. Financial hardship was determined by the question ‘Have you or your family had to go without things you really needed in the *last year* because you were short of money?’ Responses of either ‘Yes, often’ or ‘Yes, sometimes’ were coded as 1 (experienced hardship) and a response of ‘No’ was coded as 0 (no hardship). A more detailed measure was introduced at wave two, which was used in the cross-sectional analyses (this measure is described within that analyses chapter, Chapter 3).

2.4 Statistical Analyses

This section provides a brief overview of the statistical analyses conducted in this thesis, with further detail provided in each chapter. Data analysis was conducted using the statistical software package Stata/SE version 13.0. The statistical analyses that were selected

to examine the cross-sectional and longitudinal data to investigate associations between job strain and BMI are described below, in combination with the rationale for the selection of each statistical analysis technique. Prior to the analysis of the data, the data were screened for any errors (i.e., out-of-range values, incorrect coding) and cleaned accordingly.

As described earlier, in all analyses, missing observations were removed from the analysis. BMI was the variable with the most missing data in the cross-sectional analyses using wave two data (males 4.75% and females 7.58%), and in the longitudinal analyses, missing data on BMI at each wave ranged from 0.61% to 7.43% for males and from 1.27% to 8.38% for females. While there were considerable missing data on this variable in the longitudinal analyses, the analyses techniques used all observations that were available at each wave to increase the power and precision of the analyses.

2.4.1 Cross-Sectional Analyses

Cross-sectional analyses were initially conducted in this program of research to investigate whether there was an association between job strain and BMI at wave two. It was initially important to employ cross-sectional analyses because this was consistent with the data available and the methodologies employed in the majority of prior research examining this topic. Further, given that an association between job strain and BMI has rarely been considered in an Australian population, and never before in Canberra or the surrounding regions, or reported on in the PATH cohort study, it was important to begin by examining a potential cross-sectional relationship. Wave two was selected as the wave to inform the cross-sectional analyses because it had the most complete information on job strain for two cohorts (20s and 40s), thereby increasing the power of the analyses via increasing the sample size available.

The analysis of BMI continuously and categorically is both complementary and beneficial, with the analysis of BMI categories alone noted as a possible limitation of prior

research (discussed in Chapters 3 and 4). Further, to date, Australian research on job strain and BMI has only analysed BMI continuously. Given these factors, it was decided that two parallel statistical techniques would be undertaken: a) multinomial logistic regressions, which would examine BMI categorically, and b) linear regressions, whereby BMI was a continuous dependent variable. Two cross-sectional models were established for testing in multinomial logistic regressions and subsequently with linear regressions: model A tested job strain (v. all other categories as the combined reference group) exclusively as a predictor of overweight and obesity; and model B tested job strain inclusive of all selected covariates.

The multinomial logistic regressions used the BMI categories of normal weight (as the reference group), overweight and obesity as the dependent variable. The continuous measure of BMI was used in the linear regression models, which tested job strain predicting continuous BMI. The models were tested separately for males and females because the existing literature suggests that the effects may be different depending on sex (Brunner et al., 2007; Klingberg et al., 2019; Solovieva et al., 2013; Taouk et al., 2019).

2.4.2 Longitudinal Analyses

2.4.2.1 Multilevel Models

Subsequent to the cross-sectional investigations, longitudinal analyses using the full power and advantages of the four waves of data collected by the PATH study were conducted for the 40s cohort. Guidance and teachings on how to conduct and conceptualise longitudinal modelling were informed by multilevel teachings on examining change over time (Singer & Willett, 2003). Data collected from the same participants over time are highly correlated, known as intercorrelations or dependence within the data, and the multilevel analytic models are able to account for complex dependence structures by allowing the nesting of variance of lower levels within higher levels—for example, the nesting of individuals belonging to groups, given that the group exerts an effect on all members contained within it (Singer &

Willett, 2003). Within the PATH dataset, the responses of each participant are nested within the individual over time, and the longitudinal models account for individual heterogeneity in both the intercept and slope estimated (Torres-Reyna, 2007).

In panel datasets such as the PATH study, non-response are common as a result of attrition, refusal to answer, or missing at random, among others. A benefit of multilevel models is that they are robust to missing data, and it is not necessary to omit a participant's data if data are missing at any wave. This allows participants to respond at some waves of data collection, and not others, and still be included in analysis, because random coefficient models estimate model parameters using all of the available data (Hedeker & Gibbons, 2006). This reduced sensitivity to an unbalanced study thereby increases the power of the analysis and, given its ability to include as many participants' observations as available, makes the model more representative of the population from which the sample was drawn.

In this thesis, both random and fixed effects multilevel models (MLMs) were adopted to explore the possible relationship between job strain and BMI over time. The usage here of the terms 'fixed' and 'random' effects must be explicitly clarified due to differences in the terminology across differing statistical packages and disciplines of study. The random effects models employed here allowed for the inclusion of both time-varying and time-invariant variables as predictors within models. The random effects models investigated change in BMI over time as a product of both stable characteristics (i.e., sex) and variables that were able to change from wave to wave (i.e., working hours), although one limitation of these models is that the stable (i.e., time-invariant) and changing (i.e., time-varying) contributions of each independent variable to BMI over time are mixed. In contrast, the fixed effects models excluded any effect of time-invariant variables (including unmeasured heterogeneity) in order to model average changes in the predictors with average change in the dependent variable. All of the models were run using the unstructured correlation matrix. This was the least

restrictive selection to account for the potential unequal dependence of the observations (Twisk, 2013).

Given the uncertain and mixed results reported in previous literature, this thesis aimed to be comprehensive and test the data in a number of different ways. Thus, four sets of MLMs were chosen to explore the data to investigate differences in how a relationship between job strain and BMI over time may present (see Figure 2.3 for a visual overview). The four sets of models were constructed and tested in two versions: model A and model B. The restricted version (model A) included only the main predictor of interest alongside a time indicator variable in the longitudinal models (representing each wave of the PATH study). The fully adjusted version (model B) included the main predictor variables of interest alongside all relevant covariates (listed and described above). Thus, each set of models—set one, two, three, and four—had two versions: model A and B. All models were tested separately for males and females.

Model one: general random effects model: This model was a random effects model that examined the average association of job strain with BMI at each wave, and then estimated the average association across all waves. In this manner, it was the least restrictive of the sets of models employed because it reported the most general estimate of association across all waves of data. In this framework, a random intercept and slope was allowed for each individual, absorbing the inter-individual variation present in the data (Torres-Reyna, 2007).

Model two: baseline job strain model: This model also used a random effects model to explore any differences in the association of reporting job strain *specifically at wave one* with BMI over the subsequent study period. In this manner, baseline job strain was the main predictor of interest, and the average association was estimated between reporting job strain

(or not) at wave one and BMI at all waves. This model provided insights into any longer-term associations of reporting job strain with BMI across the subsequent 12 years.

Model three: fixed effects model: This fixed effects model was designed to examine, in particular, whether any changes in job strain co-occurred with changes in BMI. As the fixed effects model removed time-invariant variables, such as education, it reported on the average association of any change in job strain at each wave with any changes in BMI at each wave. That is, because the fixed effects model only includes within-person change, it minimises the effect of time-invariant (unobserved) heterogeneity, taking a step closer to identifying causal associations.

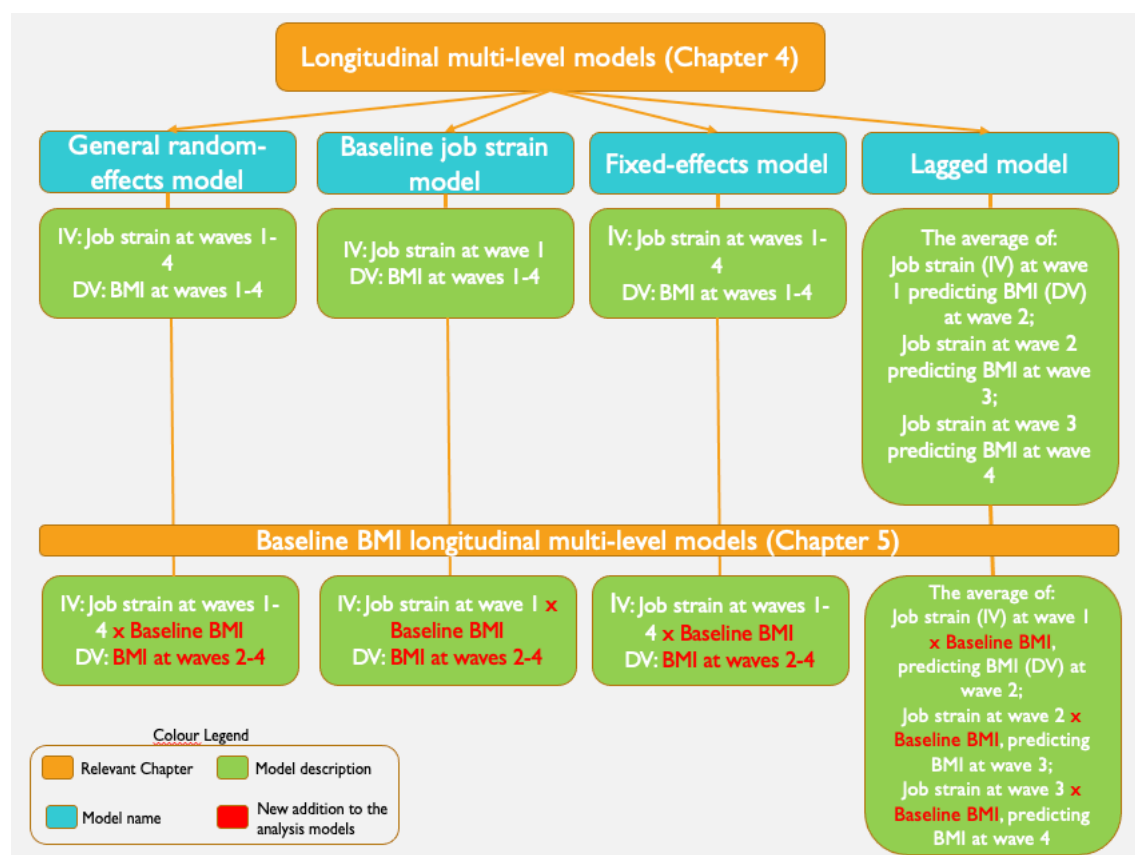
Model four: lagged model: The final model employed modelled an association of job strain at a prior wave, with BMI at a subsequent wave. Thus, if job strain was reported at wave one, this lagged model examined the subsequent association between that report of job strain with BMI at wave two. As the model estimates average associations, each available lag, from wave one to two, two to three, and three to four, was examined, and an estimate was produced for the average association of the lag. However, the first lag, from wave one to two, was used as the comparison lag for reference. Thus, the average of two lags, from wave two to three, and from wave three to four, was estimated. Effectively, this modelled an association of job strain with subsequent BMI four years later.

The four longitudinal analytic MLMs described are featured twice in the current thesis. The first is in response to the need to investigate an association of job strain with BMI over time using longitudinal data from the same individuals. In these MLMs, the main predictor of interest was job strain, entered at both model A and model B for each set of models. The second time these four sets of models are featured is in a follow-on chapter (see Chapter 5), with the introduction of research and theory noting the potential importance of BMI at baseline interacting with job strain, possibly moderating associations with later BMI

outcomes. Thus, the four sets of models were re-employed, with the main predictor of interest an interaction term between job strain and participants' BMI at wave one, baseline, entered in both model A and model B. Because BMI at wave one was entered as a predictor variable in these models, it required the exclusion of BMI at wave one as a dependent variable, rendering only waves two, three, and four available for analysis as the dependent variable.

Figure 2.3

Overview of the Longitudinal and Baseline Longitudinal Analytic Models



Note. Each MLM was constructed and tested in two versions, termed model A (restricted without adjustment for covariates) and model B (fully adjusted for covariates). Each model was repeated stratified by sex.

2.4.2.2 Accumulation Models

The fourth set of analyses employed in this thesis also examined the potential association of job strain and BMI at follow-up, but with a focus on whether reporting job strain on more than one occasion can accumulate to be associated with later BMI outcomes at

wave four. In examining whether there was an accumulation of job strain, a cumulative job strain variable was constructed. Only those who were employed at all waves, with complete data on all job strain variables (i.e., job control and demands) and BMI at wave four were selected for analysis (wave four BMI data were necessary for the analysis, and nearly all of those with wave four BMI data also had complete job strain data). The independent variable was the number of counts of job strain over the four waves of data, which were counted in a categorical variable, zero counts, one count, two counts, three counts, and four counts of job strain were combined categorically to maximise numbers, as per similar prior studies (i.e., Brunner et al., 2007; Taouk et al., 2019). This predictor variable was then entered into linear regression models predicting BMI at wave four as the outcome variable. The same linear regression model was re-employed to test the interaction of job strain accumulation and BMI at baseline on BMI outcomes at wave four.

2.5 Summary

This chapter explained the overall methodology for the PATH Through Life study, with a focus on the specific sample, variables, and analyses used in this thesis. The following chapters move into the empirical analyses undertaken, with each chapter beginning with a review of the relevant literature before describing the specific aims and results relevant to that chapter.

Chapter 3: Cross-Sectional Chapter

3.1 Chapter Summary

This chapter seeks to review the state of the cross-sectional literature directly concerned with job strain and BMI outcomes. As outlined in the introduction of this thesis, direct and indirect pathways between job strain and BMI outcomes have been proposed (via biological mechanisms, health behaviours, and other broader drivers related to each), and research examining these pathways provides a strong rationale to expect a relationship. However, this chapter shows that the results of cross-sectional investigations between job strain and BMI do not provide clear evidence for an association. As will become evident, the state of the literature includes a high degree of inconsistency in both the findings and methodologies that have been used to investigate the presence of an association.

The narrative of this chapter begins with a summary of Overgaard et al.'s (2004) review of early studies on job strain and BMI. Following this, more recent research is reviewed that highlights potential conceptual, methodological, and analytical issues. In particular, a general distinction is apparent: where some studies examine categories of BMI (overweight and obesity exclusively), others focus on continuous BMI. This inconsistent operationalisation of BMI in the literature builds the case for further research that analyses BMI continuously alongside categorical analyses to explore whether inconsistent findings might be a result of inconsistent operationalisation of the measure. Additionally, the literature review in this chapter shows a paucity of studies informing an association between job strain and BMI outcomes in the Australian population, thereby identifying a need for further studies in the Australian context in particular.

Following the literature review and exploration of methodological inconsistencies, this chapter describes cross-sectional analyses that explore associations between job strain (and its components) and BMI (as both a categorical and a continuous outcome variable) using the PATH Through Life dataset.

Methods: Data collected at wave two from the 20s and 40s age cohorts from the PATH Through Life longitudinal survey were used in the current analyses. There were 1,944 males and 1,978 females employed in paid work and available for inclusion in the analyses. Multinomial logistic and linear regression analyses modelled a relationship between job strain with both BMI categories and continuous BMI.

Results: Multinomial logistic regressions demonstrated no evidence of an association between job strain and overweight or obese BMI categories. The results of the linear regression models, with BMI analysed as a continuous outcome, were consistent, with no association between job strain and BMI for males or females.

Discussion and conclusions: No evidence of a direct association between job strain and overweight or obesity, or BMI as a continuous outcome, was found. The similarities and discrepancies between these results and those of prior studies are discussed, raising the need for longitudinal research as a suitable next step. The relationship between job strain and BMI over time should be examined using longitudinal analysis techniques to explore individual variation over time, which may assist in clarifying whether job strain is associated with BMI.

3.2 Cross-Sectional Literature Review

The majority of studies that have analysed the relationship between job strain and BMI outcomes have used cross-sectional study designs and analysed data on job strain and BMI measured at one time point only. As explained below, the early literature in this area had a focus on obesity (and risk factors for obesity) in particular, and thus tended to explore job strain in relation to scoring above the BMI cut-point that classified ‘obesity’.

3.2.1 Job Strain and Obesity: A Summary of Earlier Findings

Reflecting the disproportionate focus of research on obesity rather than other BMI outcomes, Overgaard et al. (2004) conducted a comprehensive systematic review of the earliest studies investigating an association between general work stress, inclusive of job strain, and obesity. Because much future work in this field builds on this review, it is the starting point in this chapter to describe the available cross-sectional evidence.

Between 1986 and 2001, Overgaard et al. (2004) found 10 cross-sectional studies that reported on an association between general work stress and obesity. In line with the scope of this thesis, only the studies that used the JDC model in association with BMI obesity are focused on. Overgaard et al. provided comprehensive tables summarising the studies they reviewed in their paper (see Appendix C). Because the theory and research indicate possible differences by sex, they reported the results separately for both males and females (Grunberg & Straub, 1992; Torres & Nowson, 2007). Their review of sex differences was enabled by most prior studies (but not all) stratifying their analyses by sex.

In total, eight studies reported results for males, six of which were based on the JDC model. Focusing on a traditional threshold of .05 to determine statistical significance (as seen in Appendix C), two of the six studies found support for a positive association between job strain and obesity, while the remaining four showed minimal evidence. The sample sizes of the studies reporting a significant association were small but adequate for epidemiological research (748 and 1,377 males), although slightly smaller than the sample size of studies reporting no association (range: 248–3,531 males, with an average of 1,600 males). Overgaard et al. (2004) did not report any measures of effect size, making it difficult to compare the strength of associations/effects between studies that reported significant results and those that did not. Despite this, with null findings dominating, Overgaard et al.

concluded that there was little evidence for an association of job strain with obesity in males in this early research.

For females, six studies reported on overall job strain as measured by the JDC model and obesity, four being the same as those that reported on males and two reporting results for females exclusively (Overgaard et al., 2004). Again, Overgaard et al. noted that two studies reported positive associations, two indicated the presence of a negative relationship, and two indicated no relationship between job strain and obesity. One of the studies reporting a positive association was attenuated after adjustment for relevant covariates (age, education, demography, working conditions, etc.), indicating that a relationship with obesity could be explained by variables other than job strain.

The two studies that reported negative associations of job strain with obesity did so within three different study populations of females (Amick et al., 1998; Theorell et al., 1993, as cited in Overgaard et al., 2004). Specifically, the studies found that those females who experienced job strain were less likely to be obese than their counterparts who did not experience job strain. The negative association reported by Amick et al. (1998) and Theorell et al. (1993) remained significant after adjustment for relevant covariates. However, it is worth noting the small sample size (56 participants) in Theorell et al., and that the sample of Amick et al. was drawn from a specific work industry (the Nurses' Health Study), which may have produced a biased result in comparison to the larger and more diverse epidemiological studies reviewed.

Further, one of the two studies that found a positive association for both males and females (Netterstrom et al., as cited in Overgaard et al., 2004) used an 'objective' operationalisation of job strain. To determine objectivity, an aggregated job strain score was calculated from several individuals' (subjective) job strain scores sampled across several

closely related work units of individuals. Analysis of the individual scores in this study revealed no evidence for an association (Overgaard et al., 2004).

3.2.2 Job Demands, Job Control, and Obesity

Overgaard et al. (2004) also reviewed each study for any examination of the subscale components of job strain, job control, and job demands. Regarding these, five of the studies reviewed by Overgaard et al. reported results for males (Brisson et al., 2000; Georges et al., 1992; Hellerstedt & Jeffery, 1997; Jonsson et al., 1999; Landsbergis et al., 1998, as cited in Overgaard et al., 2004). Of these, only one reported a significant positive association of obesity with both job demands and control, although this association only emerged after controlling for education, age, and smoking (Georges et al., 1992, as cited in Overgaard et al., 2004). Of the studies with females, just three reported on associations of obesity with the individual job demands and control subscales: two studies reported null results (Brisson et al., 2000; Jonsson et al., 1999) and one showed a significant positive relationship between job demands and control with obesity (Hellerstedt & Jeffery, 1997). However, in this study, only the association with job demands remained significant after controlling for covariates able to explain the presence of the association.

In summary, Overgaard et al. (2004) concluded that the clearest trend to become evident from the results across both males and females was that no consistent relationship between obesity and either job strain, job control, or job demands could be found. While a few studies reported positive associations both within and between genders, there was no consistent pattern of results. Overgaard et al. noted that the sample size of the studies that found associations was generally smaller in comparison with the larger studies, strengthening the notion that perhaps the significant association reported by those studies had occurred by chance (i.e., a type one error). This early review also pointed towards inconsistencies in not only the results but also potentially the methods in the cross-sectional literature examining

job strain and obesity. Following on from this, more consistent results may be found if inconsistencies in these methods can be better understood and/or minimised.

3.2.3 Job Strain and BMI: An Updated Account of Findings

Although Overgaard et al.'s (2004) review of the early literature is important, their findings seem to contradict theory and past research demonstrating linkages and pathways between stress and BMI outcomes. It is difficult to provide a sound explanation for why strain experienced in the workplace may not be related to BMI when there is evidence that stress more broadly is linked to adiposity, weight, and BMI. Accordingly, further cross-sectional studies, reviews, and meta-analyses (see Tables 3.1 and 3.2) were conducted after Overgaard et al.'s review, to attempt to clarify whether there was any evidence for an association. There were mixed findings among these studies: some were in line with the null conclusions of Overgaard et al. and some provided contrary evidence of a small association between job strain and BMI. The evidence from this more recent cross-sectional research is reviewed in this section, and details of the key studies are summarised in Tables 3.1 and 3.2.

In a large study, Kouvonen et al. (2005) analysed 7,936 male and 33,936 female Finnish public sector employees' responses to the JDC questionnaire in association with BMI (see the individual scores in Tables 3.1 and 3.2). In males, they found that job strain was positively and significantly related to BMI, although adjustment for SES attenuated this finding (though it was still statistically significant). The authors simultaneously reported job demands to have no significant association with BMI in males, and while job control had a negative significant relationship with BMI, this was attenuated after adjustment for occupational class. For females, the pattern of results was similar to males, with job strain being consistently positively associated with BMI even after adjustment for occupational class. Job control had a negative association with BMI, although this became non-significant after adjustment for occupational class. Job demands demonstrated a negative association

with BMI, although notably, a reversal of this association was observed after adjustment for occupational class, indicating a positive relationship thereafter.

Kouvonen et al. (2005) used linear regression to examine the association of job strain, job demands, and job control scores with BMI scores. The variables were entered continuously in analysis—job strain was operationalised as a ratio of job control with demands. While evidence was found to support an association between higher job strain and males' and females' increased BMI, it is difficult to comment on the size of the relationship because Kouvonen et al. reported beta coefficients standardised in these ratio units to represent the relationship with BMI. However, as explained in further detail below, more recent studies that have also found statistically significant findings have provided estimates indicating the size of the relationship between job strain and BMI, which indicate it is very modest (e.g., small) in size.

As an example, Fernandez et al. (2010) analysed the association of job strain with continuous BMI using a combined sample of 2,782 male and female American employees. They reported that those experiencing job strain were approximately one BMI unit higher than employees in passive job types, and this difference was statistically significant. A strength of Fernandez et al.'s study was that they concurrently modelled the relationship between job strain and the overweight and obese BMI categories (combined). The results of the analyses provided convergent evidence for the association of job strain and BMI, because job strain was associated with 45% increased odds of overweight and obesity in models adjusted for covariates. However, the association with both continuous and categorical BMI outcomes were attenuated when adjusted for further mediating factors—specifically, diet quality, physical activity, and sedentary behaviour—suggesting that these variables explained the relationship between job strain and BMI initially observed.

A later meta-analysis of 13 studies by Nyberg et al. (2012) provided further evidence of a small association between job strain and overweight and obesity. The authors conducted the largest meta-analysis to date by pooling more than 160,000 participants' responses to the JDC questionnaire along with corresponding BMI information, and concluded that there is consistent evidence for a weak association between job strain and obesity in their cross-sectional analyses. Nyberg et al. tested both job strain and its individual components—high job demands and low job control—for an association with the overweight and obese 1 and 2 (morbid obesity) BMI categories. In testing job demands, their results were not statistically significant, although the authors noted the suggestion of an association between reporting higher job demands with overweight and obesity in a dose-response fashion. The testing of average job control scores among differing BMI categories returned similar null results: while there was a suggestion of lower average job control in those who were underweight, overweight, and obese relative to the normal weight category, these estimates became non-significant after controlling for SES.

However, the testing of job strain demonstrated significantly increased odds of 12%, 7%, 19%, and 30% for reporting job strain in the underweight, overweight, obese BMI class 2 and combined obese BMI class 2/3 groups respectively in a 'U'-shaped pattern, with normal-weight individuals (as the reference group) demonstrating the least risk for job strain at the bottom of the 'U'. With further adjustment for SES, the magnitude of the estimates was attenuated to 12%, 1%, 7%, and 14% respectively. The estimated 1% risk of job strain in the overweight category became non-significant, leaving only the associations between categories of obesity and job strain statistically significant. Regarding the overall pattern of association, the sharp gradient of the 'U' was degraded but still evident (Nyberg et al., 2012), even with the attenuated statistical non-significance of the overweight category. Despite the

statistical significance of job strain in the obese categories, the results indicated only a very modest size of association between job strain and obesity that increases with increasing BMI.

Nyberg et al.'s (2012) study has many strengths that garner confidence in the results. Perhaps the most notable strength is the vast number of participants analysed compared to previous studies that have had (at most) one-third of the number of participants. Large participant numbers provide higher levels of power to the analyses to detect the presence of even modest, or weak, effects. In addition, the large participant pool was amalgamated from the results of 13 different European population datasets, affording more generalisability than previous studies, which potentially implies that the relationship between job strain and obesity shares a common aetiology across cultures. Further, Nyberg et al. reported using conservative data harmonisation techniques when analysing each dataset rather than studying specific values, which the authors noted would lead to an underestimation of their estimates if bias was apparent rather than an overestimation. The authors stated that the likelihood of a random error influencing their reported associations was low given their large sample size.

Nyberg et al.'s (2012) cross-sectional results are broadly in agreement with those of Azagba and Sharaf (2012), who reported an association of job strain with BMI (analysed continuously) in cross-sectional analyses. Azagba and Sharaf analysed data for 28,371 males and females on three levels of job strain (high, medium, and low) in association with BMI. They found that high job strain was significantly associated with higher BMI compared to those reporting low strain, and the association was graded by the level of job strain exposure, with medium levels of job strain also being significantly associated with increased BMI relative to individuals reporting low job strain, although the size of the association was lower than those reporting high job strain. The associations reported were robust to adjustment for a range of demographic factors, SES, health conditions, and lifestyle behaviours, including exercise patterns.

However, further research is required to demonstrate the replicability of cross-sectional results such as those of Nyberg et al. and Azagba and Sharaf, especially because other earlier studies, conducted after the review by Overgaard et al. (2004), did not find an association between job strain and BMI, leaving the state of findings mixed. For example, Lallukka et al. (2008) analysed the association between job strain and obesity across three separate samples of employees from London, Helsinki, and Japan. Although all of the confidence interval estimates included zero and were thus not statistically significant, the models estimated the odds for obesity as 37% and 22% higher for those reporting job strain among the London and Helsinki employees, respectively, compared to those not reporting job strain. While also not significant for the Japanese employees, a converse 14% reduction in the odds for obesity were reported given job strain. Another large study of male and female Japanese workers employed in a rural metal factory returned no evidence that the components of job strain, job demands, and job control were associated with BMI (Ishizaki et al., 2004).

Further adding to the need for clarity, a systematic review of studies analysing job strain and obesity by Solovieva et al. (2013) concluded that the evidence for an association of psychosocial factors at work, including job strain, low job control and high job demands, was weak and inconsistent. This conclusion is reflective of studies that found no evidence for a cross-sectional association between job strain and BMI, and contrasts with studies that found evidence, including the cross-sectional results of the meta-analysis by Nyberg et al. (2012). However, some findings of Solovieva et al.'s systematic review are important to consider when evaluating the evidence presented. For instance, the authors noted that studies with higher-quality methodologies were more likely to have detected a significant association when compared with studies deemed to be of lesser quality. Their standard of high quality

was assessed as containing none, or only possible, bias (specifically, selection, performance, detection, and attrition), which was determined using Cochrane quality criteria guidelines.

This finding of Solovieva et al. (2013) is further supported by a review and meta-analysis conducted by Wardle et al. (2011), who examined linkages between psychosocial work stress (including job strain) and adiposity as part of a broader review on stress and adiposity. In agreement with Solovieva et al., Wardle et al. also concluded that studies with higher-quality methodologies were more likely to have detected significant effects. However, the findings of Fernandez et al. (2010), Kouvonen et al. (2005) and Lallukka et al. (2008) (discussed above) were assessed in Solovieva et al.'s review as having none or only minor possible bias; however, the results of these studies are still discrepant, indicating that there are inconsistencies even among high-quality studies with little or no bias.

3.2.4 Continuous and Categorical BMI Outcomes

Alongside the need for further research to clarify evidence for an association between job strain and BMI, other factors related to study design and methodological considerations may assist in understanding the inconsistency present. Observing the body of literature, one consideration is whether findings differ based on whether BMI has been examined as a continuous or a categorical variable. When treated as a categorical variable, obesity is predominantly the outcome of focus, most often indicated by a BMI greater than 30 (in accordance with WHO recommendations), which represents the higher end of BMI distribution. Because obesity is based on BMI level, research investigating continuous BMI and obesity are related and often complementary. However, given the underlying differences in health profiles and the increased health risk potentially indicated by BMI category membership, there are differences in the information generated by investigating BMI either way, and risk associated with obesity may be different from other BMI categories or the whole of the BMI distribution.

Fernandez et al.'s (2010) study is an example of the complementary nature of simultaneously investigating continuous and categorical BMI overweight and obesity for an association with job strain. Without accounting for exercise and sedentary behaviours, the results of the dual analyses indicated significant positive associations, with job strain estimated to be associated with a one-unit increase in BMI across the BMI distribution, and with 45% increased odds of overweight and obesity. The positive association with continuous BMI indicates an effect across the distribution of BMI tested—an average association regardless of BMI category or level. Further, the significantly increased risk reported for overweight and obesity suggests that job strain is associated with increased risk of being overweight and obese specifically, compared with those who are normal weight.

Considering the related, although differing, information conveyed by each approach, there is further inconsistency in the literature regarding whether job strain may be associated with higher BMI across the distribution (continuously) or exclusively with obesity. For example, the results of Nyberg et al. (2012) demonstrated an association of job strain with overweight in addition to obesity until adjustment for SES was accounted for, at which point only obesity was significantly associated with increased odds of job strain. However, Fernandez et al. (2010) reported a positive significant association of job strain with overweight and obesity even when controlling for measures of SES, and the association for both was attenuated when accounting for exercise and hours of sedentary TV viewing. However, it is difficult to know whether an association of job strain with increased risk for obesity exclusively may have remained in the analyses conducted by Fernandez et al., because overweight and obesity were combined in the analyses.

The evidence presented in Tables 3.1 and 3.2, and the studies reviewed by Overgaard et al. (2004), demonstrates further inconsistencies in whether job strain may be associated with an average increase in BMI across the distribution, or exclusively with obesity. Among

the studies that analysed BMI categorically, some have reported significant associations (Amick et al., 1998; Fernandez et al., 2010; Nyberg et al., 2012), while others have reported null associations (Brisson et al., 2000; Lallukka et al., 2008; Wamala et al., 1997, as cited in Overgaard et al., 2004). This is also the case in studies that have analysed BMI continuously, with some (Azagba & Sharaf, 2012; Fernandez et al., 2010; Kouvonen et al., 2005) reporting a significant association, and others (Ishizaki et al., 2004; Jonsson et al., 1999; Ostry et al., 2006) concluding that there is limited evidence. Thus, in combination with doubts regarding whether an association between job strain and BMI outcomes exists at all, it is unclear whether job strain is associated with obesity or BMI more generally. Further research analysing each would be beneficial for clarity.

3.2.5 Job Strain and BMI Outcomes: Lacking an Australian Focus

Work stress, of which a contributor is job strain, is a prominent issue in Australian working life (Black Dog Institute, 2021) and has been reported by Safe Work Australia (2013) as the second most common cause of workplace compensation claims. Work-related mental stress and stress claims in Australia have increased in recent decades concurrently with increasing BMI, which is another problematic health issue in the Australian population (AIHW, 2021; Huse et al., 2018). However, studies analysing Australian data on job strain and BMI are lacking, with just one study reporting on this association to date (Ostry et al., 2006), and only one other reporting on the component subscales: job demand and job control subscales with BMI (Bean et al., 2015). Of these two studies, Ostry et al. (2006) found that high job demands were associated with increased BMI in males, but noted no significant associations for job strain or job control, and no association at all in females. In combined sex analyses, Bean et al. (2015) did not find a significant association of job demands with BMI. The authors tested job control separated into its subscale components of decision authority and skill discretion. They found that skill discretion had a negative relationship

with BMI, while evidence was found for a positive relationship between decision authority and BMI. However, the negative significant association of skill discretion with BMI was observed at a more conservative alpha level (i.e., .01) than the positive association between decision authority and BMI (which was only significant at a liberal alpha level of .1). Thus, there was stronger statistical evidence for a negative association of skill discretion with BMI—that is, as skill discretion decreased, BMI increased.

However, while both studies used continuous BMI in linear regression analyses, the findings between Bean et al. and Ostry et al. are not easily comparable because Bean tested job control as its components subscales and did not test job strain at all. Further, both studies were carried out with samples from different Australian states (i.e., different geographical locations). Bean et al. analysed South Australian data, while Ostry et al. used a Victorian population sample. The large distances between Australian cities, combined with different state-level employment and work-related policies, and the varying socioeconomic profiles of Australian cities, are potential sources of variation that may be reflected in the differing findings of the studies. Further, Bean et al. noted the small sample size (450 males and females combined) as a limitation of their analyses, recommending further analysis of job strain and BMI with a larger sample. While the sample analysed by Ostry et al. was larger (427 males and 455 females), further Australian studies with larger datasets would be a beneficial addition to the body of research.

While these are the only two studies found in the current thesis to have specifically modelled the JDC in association with BMI, there is broader evidence of an association of adverse occupational factors with BMI in Australian workers. For example, Magee et al. (2010) reported evidence that occupational factors—specifically, inflexible working hours and weekend work—are associated with BMI increase. Another Australian study found high-quality evidence for a relationship between job adversity and BMI. Taouk et al. (2019) used

a measure of job adversity that included measures of job demands and control, reporting a significant relationship of job adversity with continuous BMI over time in a nationally representative population sample. While not directly comparable with the cross-sectional research reviewed here (because of their use of broader occupational factors and job adversity measures and longitudinal designs), the results of Magee et al. and Taouk et al. provide promising evidence to suggest that there may be a relationship. Taouk et al. may have also found supportive evidence as a result of the larger sample size analysed (14,949 participants), which afforded the study greater power to detect an effect in line with the recommendations of Bean et al. (2015). Further investigations into an association between job strain and BMI outcomes specifically within Australian populations are warranted.

While each Australian study noted some significant associations of elements of job strain with BMI, further research is needed to piece together further evidence for an association in the general, and specific state, populations. Further, no Australian studies have tested an association with obesity to date, identifying an unexplored area within Australian data.

3.3 Aims

After reviewing the cross-sectional literature regarding job strain and BMI outcomes (including BMI as a continuous and a categorical measure representing overweight and obesity), it is apparent that the findings are not clear or consistent: null, positive, and negative associations have all been reported, including discrepancies among studies and within study populations. If an association exists, it is likely to be weak, and small sample sizes (related to lower power) may be one factor, among others, to have influenced the inconsistency in findings. However, as reviewed in the introductory chapter of this thesis, given the concurrent increases in both job strain incidence and BMI over time, and given the evidence and theory that supports both direct and indirect pathways between these two

phenomena, there are good reasons to attempt further investigations to understand and clarify potential associations. Thus, the remainder of this chapter aims to provide cross-sectional data and results to further examine whether there is an association between job strain and BMI outcomes.

The analyses in this chapter use cross-sectional PATH data to examine the association of job strain with continuous BMI, and also with overweight and obese BMI groups compared to normal-weight individuals. While the focus of this thesis is job strain, the core components of job strain—high job demands and low job control—are also tested in these cross-sectional analyses to provide a comparison with the existing literature. Given the lack of consistency in the literature to provide direction, no hypotheses are specified, although these analyses aim to extend the prior literature by investigating whether the results are replicated or attenuated depending on the use of categorical and continuous BMI variables. Additionally, given the lack of Australian research examining the link between job strain and BMI outcomes, by using representative population-based data from Canberra and the surrounding region, this chapter further expands the available research examining job strain and BMI specifically in Australia.

Although some previous studies have combined sex in analysis (i.e., Fernandez et al., 2010; Nyberg et al., 2012), differing results have been found by sex within and between studies (e.g., Hellerstedt & Jeffery, 1997; Ostry et al., 2006; Solovieva et al., 2013). This is also consistent with other research demonstrating possible differences in responses to more general stress and occupation-specific stress by sex (e.g., Joseph et al., 2018; Papier et al., 2015; Taouk et al., 2019). Given this evidence that the association between stress and BMI may differ among males and females, the following analyses were stratified by sex.

Table 3.1

Cross-Sectional Study Results for Associations Between Job Strain and JDC Scales and BMI Outcomes for Males and Combined Sex Studies

Study	N	Population details	Outcome	Covariates	Analysis information	Job demands	Job control	Job strain
Ishizaki et al. (2004)	4,243 males	Industrial employees, Japan	Continuous BMI	Age	General linear model method predicting BMI from categorical JDC scales	Job demands tertiles (mean BMI): Low: 23.15 Middle: 23.01 High: 23.12 P=.42	Job control tertiles (mean BMI): Low: 23.03 Middle: 23.00 High: 23.24 P=.05	—
				Age, smoking, alcohol, exercise, education, marital status	Stepwise linear regression predicting BMI from categorical JDC scales	—	B=.101, F 2.5, p=.11	—
Kouvonen et al. (2005)	7,936 males	Finnish public sector employees	Continuous BMI—self-report	Age, marital status, job contract, smoking, alcohol, leisure physical activity, negative affectivity	Linear regression (standardised beta coefficient reported), continuous JDC variable predicting BMI scores	Individual: NS. B=0.00, (p>.05)	Individual: Negative relationship B=−.06, (p<.001)	Individual: Positive relationship B=.04, (p<.001)
						Aggregated: Negative relationship B=−.08, (p<.001)	Aggregated: Negative relationship B=−.12, (p<.001)	Aggregated: Positive relationship B=.04, (p<.001)
						+ occupational class Individual: NS. B=0.01, (p>.05)	Individual: NS. B=−.02, (p>.05)	Individual: Positive relationship B=.02, (p<.05)
						Aggregated: Negative relationship	Aggregated: Negative relationship	Aggregated: NS. B=−.01, (p>.05)

Study	N	Population details	Outcome	Covariates	Analysis information	Job demands	Job control	Job strain
						B=-.06, (p<.001)	B=-.08, (p<.001)	
Ostry et al. (2006)	427 males	Australian employees	Continuous BMI—self-report	Age, marital status, education	Linear regression; job variables median split	High job demands predicts BMI (B=.87, p=.04)	Low job control predicts BMI (B=-.40, p=.34)	Job strain predicts BMI (B=.50, p=.42)
Lalluka et al. (2008)	1,747 males	White-collar employees, London	Categoric BMI—measured	Age, occupational class, marital status, job strain, working overtime*	Logistic regression predicting obese (BMI >30) v. non-obese categories	—	—	Job strain predicting obesity. OR: 1.37 (CI95: .88–2.13)
	1,015 males	White-collar employees, Helsinki	Categoric BMI—self-report	Age, occupational class, marital status, job strain, working overtime*	Logistic regression predicting obese (BMI >30) v. non-obese categories	—	—	Job strain predicting obesity. OR: 1.22 (CI95: .75–1.98)
	307 males	White-collar employees, Japan	Categoric BMI—measured	Age, occupational class, marital status, job strain, working overtime*	Logistic regression predicting obese (BMI >25) v. non-obese categories	—	—	Job strain predicting obesity. OR: .84 (CI95: .51–1.39)
Fernandez et al. (2010)	2,782 males and females	American employees	Continuous BMI—measured	None	Linear mixed effects model	—	—	Job strain predicts BMI. (B=.88, SE=.35, p<.05)
				Age, gender, race, income, education, smoking	Linear mixed effects model	—	—	Job strain predicts BMI. (B=.89, SE=.39, p<.05)
				+ diet, physical activity, sedentary behaviour	Linear mixed effects model	—	—	NS. (B=.68, SE=.39, p>.05)
			Categorical BMI: <=24.9/ >=24.9 (overweight and obesity)	None	Generalised linear mixed model, logit link function	—	—	Significantly increased odds of Ov/Ob, OR: 1.49 (CI95: 1.13, 1.96, p>.05)

Study	N	Population details	Outcome	Covariates	Analysis information	Job demands	Job control	Job strain
			combined in analyses)					
				Age, gender, race, income, education, smoking	Generalised linear mixed model, logit link function	—	—	Significantly increased odds of Ov/Ob, OR: 1.45 (CI95: 1.09, 1.95, $p>.05$)
				+ diet, physical activity, sedentary behaviour	Generalised linear mixed model, logit link function	—	—	NS, OR: 1.34 (CI95: 1.00, 1.80, $p>.05$)
Azagba and Sharaf (2012)	28,371 males and females	Nationally representative Canadian population survey	Continuous BMI—self-report	Age, sex, marital status, education, income level, ethnicity, smoking, alcohol use, physical activity, time trend, social support, health status, occupational fixed effects	OLS regression of tertiles of job strain (ratio of demands to control) on BMI	—	—	High strain had a positive relationship with BMI ($B=.570$, $SE=.115$, $p<.001$) Medium strain had a positive relationship with BMI ($B=.220$, $SE=.095$, $p<.05$)
Bean et al. (2015)	220 males and 230 females	Employed South Australian workers	Continuous BMI—clinic measured	Sex, age, household income, working hours, white v. blue collar	Linear regression of continuous job demands, skill discretion, and decision latitude on continuous BMI	NS. $B=-.030$, $SE=.047$, $p=.527$	Skill discretion predicts lower BMI: $B=-.163$, $SE=.058$, $p=.005$ Decision authority predicts higher BMI ($B=.087$, $SE=.049$, $p=.075$)	—
Nyberg et al. (2012)	78,487 males and 83,259 females	Employed (pooled across 9	Categorical BMI—	Age, sex	Meta-analysis Mean difference (MD) on job demands/control	NS, Overweight MD: $-.01$ ($-.08$ to $.01$), obese	Lower job control scores in obese groups.	Odds of job strain higher in overweight and obese groups.

Study	N	Population details	Outcome	Covariates	Analysis information	Job demands	Job control	Job strain
	females (161,746 total)	different countries)	measured and self-report		score between overweight/ obesity and normal weight (reference) Logistic regression predicting job strain v. no job strain category from BMI category	class 1 MD: $-.02$ ($-.06$ to $.02$), obese class 2+3 MD: $-.01$ ($-.08$ to $.06$) Reference: normal weight	Overweight MD: $-.05$ ($-.07$ to $-.03$), obese class 1 MD: $-.13$ ($-.16$ to $-.11$), obese class 2+3 MD: $-.19$ ($-.23$ to $-.14$) Reference: normal weight	Overweight OR: 1.07 (1.01–1.12), obese class 1 OR: 1.19 (1.13–1.25), obese class 2+3 OR: 1.30 (1.16–1.46) Reference: normal weight
				Age, sex, marital status, smoking status, SES	As above	NS, although suggestion of dose-response relationship: Overweight MD: $.01$ ($-.01$, $.03$), obese class 1 MD: $.02$ ($-.01$, $.06$), obese class 2+3 MD: $.06$ ($-.02$, $.13$) Reference: normal weight	NS. Overweight MD: $.00$ ($-.01$ to $.01$), obese class 1 MD: $-.02$ ($-.04$ to $.01$), obese class 2+3 MD: $-.05$ ($-.09$ to $.00$) Reference: normal weight	Odds of job strain higher in obese groups. Overweight OR: 1.01 (.96–1.06), obese class 1 OR: 1.07 (1.02–1.12), obese class 2+3 OR: 1.14 (1.01–1.28) Reference: normal weight

Notes. * = Models adjusted for age only also found no significant results. This table is not the product of a systematic review of all of the literature; rather, it summarises the key studies reported in the text.

Table 3.2*Cross-Sectional Study Results for Associations Between Job Strain and JDC Scales and BMI Outcomes for Females*

Study	N	Population details	Outcome	Covariates	Analysis information	Job demands	Job control	Job strain
Wamala et al. (1997)	243 females	Swedish general population	Categorical BMI—measured: normal weight BMI<23.8; overweight 23.8–28.6; obese>28.6	Age, psychosocial stress, SES	ANOVA analysing job strain ratio per BMI category	—	—	Mean job strain ratio: normal weight: .69; overweight: .70; obese: .71 p=.07, SEM=.03 for all. Authors note that results are suggestive of higher job strain with overweight and obesity
Ishizaki et al. (2004)	2,433 females	Industrial employees, Japan	Continuous BMI	Age	General linear model method predicting BMI from categorical JDC scales	Job demands tertiles (mean BMI): Low: 21.97 Middle: 22.16 High: 22.12 P=.46, NS	Job control tertiles (mean BMI): Low: 22.13 Middle: 22.14 High: 21.97 P=.47, NS	—
Kouvonen et al. (2005)	33,936 females	Finnish public sector employees	Continuous BMI—self-report	Age, marital status, job contract, smoking, alcohol, leisure physical activity, negative affectivity	Linear regression (standardised beta coefficient reported), continuous JDC variable predicting BMI scores	Individual: negative relationship (B=−.02, p<.05)	Individual: negative relationship (xB= −.02, p<.001)	Individual: positive relationship (B=.02, p<.001)
						Aggregated: (B=−.01, NS)	Aggregated: negative relationship (B=−.09, p<.001)	Aggregated: positive relationship (B=.07, p<.001)
						+ occupational class	Individual: (B=0.00, NS)	Individual: positive relationship (B=.01, p<.05)

Study	N	Population details	Outcome	Covariates	Analysis information	Job demands	Job control	Job strain
						positive relationship (B=.01, p<.05)		
						Aggregated: negative relationship (B=-.01, p<.05)	Aggregated: negative relationship (B=-.07, p<.001)	Aggregated: positive relationship (B=.04, p<.001)
Ostry et al. (2006)	455 females	Employed, Australia	Continuous BMI—self-report	Age, marital status, education	Linear regression; job variables median split	High job demands predicting BMI (B=.23, p=.61)	Low job control predicting BMI (B=-.48, p=.31)	Job strain predicting BMI (B=-.31, p=.61)
Lalluka et al. (2008)	640 females	White-collar employees, London	Categoric BMI—measured	Age, occupational class, marital status, job strain, working overtime*	Logistic regression predicting obese (BMI>30) v. non-obese categories	—	—	Job strain predicting obesity, OR: 1.46 (CI95: .76–2.82) (low job strain as reference category)
	4,667 females	White-collar employees, Helsinki	Categoric BMI—self-report	Age, occupational class, marital status, job strain, working overtime*	Logistic regression predicting obese (BMI>30) v. non-obese categories	—	—	Job strain predicting obesity, OR: .91 (CI95: .71–1.15) (low job strain as reference category)
	307 females	White-collar employees, Japan	Categoric BMI—measured	Age, occupational class, marital status, job strain, working overtime*	Logistic regression predicting Obese (BMI>25) v. non-obese categories	—	—	Job strain predicting obesity, OR: 1.67 (CI95: .67–4.18) (low job strain as reference category)

Notes. * = Models adjusted for age only also found no significant results. # = Standardised beta coefficients. This table is not the product of a systematic review of all the literature; rather, it summarises the key studies reported in the text.

3.4 Methodology

3.4.1 Participants

This chapter used data collected from participants enrolled in the PATH Through Life survey, which is a planned 20-year longitudinal community survey based on participants from the Canberra and Queanbeyan regions. Details of the PATH data were provided in Chapter 2, but in brief, the study follows three cohorts of individuals: a group of participants initially aged 20–24 years, a group initially aged 40–44 years, and a group initially aged 60–64 years at baseline. Each cohort is interviewed once every four years to collect information to inform each wave of data.

The data in the current analyses are from wave two of the survey, collected in 2004/2005 from the 20s and 40s cohorts. Wave one data were not used because relevant job quality information was only collected from the 20s and 40s cohorts at wave two onwards. Job quality information was not collected from the 60s cohort at any wave of PATH, because many of this cohort had entered or were approaching retirement.

At wave one, 2,404 participants in the 20s cohort and 2,530 participants in the 40s cohort were surveyed. At wave two, 2,139 participants in the 20s cohort and 2,354 participants in the 40s cohort were re-interviewed (89% and 93% retention from wave one interviewees)—a total of 4,493 participants. For the current analysis chapter, participants were excluded if they were not working full- or part-time (leaving 1,959 males and 2,045 females), responded yes to being pregnant in the past 12 months (given the effect of pregnancy on the calculation of BMI; $n=53$ females), or did not have information on the required JDC scales, leaving 3,922 participants for analysis (1,944 males and 1,978 females). For males, 47.15% were in the 20s age group ($n=917$), and for females, 45.68% were in the 20s age group ($n=904$).

3.4.2 Measures

The key measures used in all analyses chapters in this thesis were described in Chapter 2. However, a brief overview of each measure and any specific information that pertains to this chapter (e.g., reliability indicators) are provided below.

3.4.2.1 *Employment, Job Quality and Overweight and Obesity Measures*

3.4.2.1.1 Employment Status

Participants were asked about their employment status and responded whether they were: 1) employed full-time, 2) part-time looking for full-time work, 3) employed part-time, 4) unemployed and looking for work, or 5) not in the labour force. Participants were excluded if they reported that they were not full- or part-time employed.

3.4.2.1.2 Job Strain

The items comprising the job demands and control scale (Cronbach's alphas .65 and .86 respectively) were taken from the Whitehall study (Department of Epidemiology & Public Health, 1991), which was modelled from the Job Content Questionnaire (Bosma et al., 1997). The items from each scale were responded to using a 1–4-point Likert scale (from 'often' to 'never') and were then summed to create a scale for job demands that ranged from 4 to 16, as well as a summary scale for job control that ranged from 7.5 to 30. Scores on the job demands and control scales were then median split (as has been done in prior research, e.g., Amick et al., 1998; Nyberg et al., 2012; Ostry et al., 2006) to create dichotomised high and low job control (median = 24) and high and low job demands (median = 11) categories. For job control, 0 represented high (scores above median) and 1 represented low (scores below median), such that higher control (the higher-quality job condition) acted as the reference category in the analyses. For job demands, 1 represented high (scores above

medium) and 0 represented low scores, such that the reference category represented the higher-quality job condition.

Following this, a job strain variable was created: high job strain (coded as 1) was indicated when participants' scores demonstrated low job control and high job demands, and all other job types (coded as 0) were indicated in the absence of this combination of scores.

3.4.2.1.3 Body Mass Index

Self-report BMI was calculated using participants' weight in kilograms divided by their height in metres squared (weight [kg]/height [m²]). Based on the WHO (2000) guidelines, four categories of BMI were formed: underweight for those whose BMI was less than 18.50, normal weight for those whose BMI was between 18.50 and 24.99, overweight for those whose BMI was between 25 and 29.99, and obese for those with a BMI greater than, and inclusive of, 30. The categories were coded 1 for underweight, 0 for normal weight, 1 for overweight, and 2 for obese. The cell size for the underweight category (n=66) was deemed too small to be included in the analyses (when categorised by job quality characteristics); thus, only the normal weight (used as the comparison group in categorical analyses), overweight, and obese categories were analysed. In accordance with prior studies (i.e., Nyberg et al., 2012; Paige et al., 2014), BMIs greater than 50 were excluded from analysis (n=6) because of concerns over the accuracy of BMI at such extremities, undue influence in analysis, potential for differing health associations with super-obesity, and small numbers. Similarly, when a continuous measure of BMI was used, those whose BMI was <18.50 or >50 were excluded, and BMI ranged from 18.51 to 47.05 for males and from 18.51 to 49.19 for females.

3.4.2.2 Covariates

3.4.2.2.1 Physical and Mental Health

Physical and mental health were assessed using the SF-12, which has two components: the PHC and the MHC. Using the RAND-12 scoring method (Windsor et al., 2006), six physical health items were scored to calculate the PHC (Cronbach's $\alpha = .72$), and six mental health items were used to calculate the MHC (Cronbach's $\alpha = .78$; Ware et al., 1996). Participants' scores for each scale were then entered continuously into each analysis.

3.4.2.2.2 Education

Years of education was controlled for in all adjusted models. Years of education is a proxy for socioeconomic position (SES), and prior research shows that BMI is related to both SES and education (ABS, 2011; Markwick et al., 2013). Although the sample median for years of education (16 years) was quite high, this is in line with the high education and SES profile of ACT residents (ACT Quickstats, 2016). Education was maintained continuously in analyses after the inclusion of a categorical education variable demonstrated no notable differences to the results of the model.

3.4.2.2.3 Work Hours

The number of hours that participants worked in a routine week, including unpaid overtime and work taken home, was controlled for in adjusted analyses, with research showing positive associations between the number of hours worked and BMI (i.e., Ostry et al., 2006; Solovieva et al., 2013). An upper range of 125 hours worked per week was observed in the dataset. This upper limit, although high, corresponds to plausible working hours and is in line with capturing the theorised reality of those experiencing job strain. Job hours was entered continuously in the analyses after the

inclusion of a categorical variable demonstrated no notable differences to the results of the model.

3.4.2.2.4 Exercise

Because engagement in physical exercise influences BMI, participants' exercise levels were controlled for in adjusted analyses. Participants were assigned to one of three categories depending on the intensity and number of hours of exercise they reported per week. This was based on the Whitehall study exercise categories (Department of Epidemiology & Public Health, 1991), whereby those reporting more than 1.5 hours of vigorous exercise per week were coded as group 2, those reporting more than 1.5 hours per week of moderate exercise, but less than 1.5 hours per week of vigorous exercise, were coded as group 1, and those reporting less than 1.5 hours of moderate exercise were coded as group 0.

3.4.2.2.5 Smoking

Current smoking has a negative relationship with BMI and was adjusted for in all analyses. Participants responded to the question 'Do you currently smoke?' with 'Yes' or 'No'. The responses were then coded into two groups (1 = 'Yes, currently smoking' and 0 = 'Not currently smoking').

3.4.2.2.6 Children

Whether participants had children or not was coded into one of two groups following their 'Yes' or 'No' response to the question 'Do you have any children?' (0 = 'No children' and 1 = 'Yes, children'). This included children who were adopted, stepchildren, and children not currently living with the participant.

3.4.2.2.7 Financial Hardship

To further control for SES (ABS, 1988), a financial hardship indicator was created where 0 represented no financial hardship and 1 represented financial

hardship. Financial hardship was determined by a positive response to any of four situations asked in the question: ‘Over the last year did any of the following happen to you because of a shortage of money: Pawned or sold something?; Went without meals?; Was unable to heat your home?; Asked for help from a welfare/community organisation?’ (Australian Bureau of Statistics, 2002).

3.4.2.2.8 Age Group

Given the positive association of BMI with age from early to later middle life (Barbour-Tuck et al., 2018; Block et al., 2013), an age-group variable identified whether the participant was aged 24–28 or 44–48 at wave two of the PATH Through Life survey to control for age statistically in the analyses.

3.4.3 Statistical Analyses

3.4.3.1 *Data Screening and Checks*

The degree of missing data was small (see Table 3.3). There were no differences in levels of job control, job demands, and job strain between those who were missing data on BMI and work hours and those who provided complete data. Based on this finding, and because the degree of missing data was so small, no imputation was conducted, and the analyses were undertaken only for those with complete data. Outliers greater than three standardised residuals were identified (26 males and 15 females). These individuals reported BMIs of 40–50. The analyses considered the potential influence on model estimation, but overall, the removal of the outliers did not change the pattern of the results for males and females. In-depth analysis of the outliers (as seen in Appendix D, section D.4 in table D.7) revealed that the range of BMIs they corresponded to across all males and females (i.e., BMIs of 40–50) was plausible and naturally occurring across the distribution of BMI and were thus retained in all analyses. Linearity checks demonstrated adequate linear

associations in bivariate analyses between the variables included across all models, including covariates, and BMI.

3.4.3.2 Statistical Models

Two sets of models were conducted to explore the association between the job strain characteristics and BMI outcomes, each repeated stratified by sex. The first models were multinomial logistic regression models (MLRMs) that modelled BMI as a categorical variable with normal weight as the reference category comparing risk with overweight and obesity. The second set of models were linear regressions, which essentially repeated the MLRMs but modelled BMI as a continuous variable. In both sets of models, the job strain variables were initially tested for a univariate relationship with overweight, obesity, or BMI (the dependent variable). Following this, covariates were included in multivariate models. Thus, there were two sequences of models with the pattern: model A—job strain; and model B—job strain with covariates. Whilst the covariates were modelled and presented in all model B (fully adjusted) analyses run, the estimates for the covariates cannot be interpreted in the same manner (i.e., as a total effects estimate) as the primary variable of investigation—job strain (Westreich & Greenland, 2013).

3.5 Results

3.5.1 Descriptive Statistics and Sample Characteristics

Tables 3.3 and 3.4 show the proportions (for categorical variables), percentage missing, means, and standard deviations (for continuous variables) for each relevant variable by sex. Similar percentages of job strain were reported among males and females, with less than one-fifth of males and females reporting job strain. Males reported an almost one-point-higher average for BMI and job control compared to females, although the means for job demands were closer. The majority of females

were of normal weight, almost one-quarter were overweight, and less than one-fifth were obese. Most males were overweight, with normal weight being the second most common BMI category and obesity being the least prevalent among males. Just over one-fifth of males and females reported current smoking, and over half of the males and females reported having children. Males reported working a higher number of hours per week than females, and consistent with this, most males reported full-time employment compared to just under three-quarters of females. Just under one-fifth of males and just over one-fifth of females reported experiencing financial difficulties. Most males reported high, or moderate, weekly exercise levels, while most females reported moderate or low weekly exercise engagement.

Tables 3.5 and 3.6 show the testing of all covariates for univariate associations with BMI categories (normal weight, overweight, and obese) separately by sex (chi-square tests and analyses of variance (ANOVAs) were used as appropriate for categorical and continuous variables, with post hoc comparisons carried out). These showed significantly higher proportions of overweight and obesity in males and females who were older (40s age group) compared with younger (20s age group), in those who had children compared with those who did not, and in those who reported only moderate or mild weekly exercise. Obese females reported significantly reduced mental health relative to normal-weight females. For men, there were no differences in mental health scores across categories of BMI. Obese males reported worse physical health relative to overweight and normal-weight males, and obese and overweight females reported worse physical health relative to normal-weight females. Obese males and both obese and overweight females had significantly fewer years of education compared with normal-weight individuals, and obese males reported working significantly more hours per week than normal-weight males.

Table 3.3*Descriptive Statistics for Each Categorical Variable by Sex*

Variable		Males			Females		
		N=1,944	%	% Miss.	N=1,978	%	% Miss.
Job strain	Yes	346/1,944	17.77	0	428/1,978	18.62	0
BMI category	Normal	738/1,883	39.13	3.13	1,081/1,851	58.31	6.42
	Overweight	843/1,883	44.70	—	432/1,851	23.30	—
	Obese	302/1,883	16.17	—	338/1,851	18.39	—
Employment	Full-time	1,800/1,944	92.60	0.00	1,470/1,978	74.32	0.00
Children	Yes	1,022/1,944	52.52	0.00	1,116/1,978	56.34	0.00
Current smoker	Yes	428/1,944	21.98	0.00	407/1,978	20.55	0.00
Exercise	Low	348/1,918	18.22	1.33	613/1,946	31.45	1.61
	Mod	709/1,918	36.91	—	797/1,946	41.05	—
	High	861/1,918	44.87	—	536/1,946	27.50	—
Finance problems	Yes	350/1,942	17.99	.10	401/1,960	20.27	0.93

Notes. This table includes data from all employed participants at wave two who had data on job characteristics, excluding those whose BMI >50 (n=6). The numbers included in the final analyses were slightly lower based on complete cases analyses (e.g., final analysis n=1,774 males and n=1,745 females).

Table 3.4*Descriptive Statistics for Continuous Variables by Sex*

Variable	Males			Females		
	N=1,944	M (SD)	% Miss.	N=1,978	M (SD)	% Miss.
BMI	1,883	26.49 (4.06)	3.13	1,851	25.58 (5.38)	6.42
Education (years)	1,944	14.73 (1.99)	0.00	1,977	14.78 (1.99)	0.05
Work hours	1,895	45.37 (12.51)	2.47	1,921	38.63 (12.78)	2.88
Rand-MHC	1,926	49.56 (8.73)	0.18	1,968	47.72 (9.47)	0.50
Rand-PHC	1,912	52.08 (6.46)	1.62	1,956	51.02 (7.56)	1.11

Notes. This table includes data from all employed participants at wave two who had data on job characteristics, excluding those whose BMI >50 (n=6). The numbers included in the final analyses were slightly lower based on complete cases analyses (e.g., final analysis n=1,774 males and n=1,745 females).

Table 3.5*Descriptive Statistics for Males by Normal Weight, Overweight, and Obesity*

		Normal weight	Overweight	Obese	N	Sig.
Age group	20	48.8%	40.4%	10.7%	903	0.000
	40	30.3%	48.8%	20.9%	980	
Employment	FT	38.2%	45.6%	16.2%	1,744	0.006
	PT	51.8%	34.5%	13.7%	139	
Children	Yes	29.9%	49.9%	20.2%	982	0.000
	No	49.2%	39.2%	11.6%	900	
Current smoker	Yes	41.9%	43.1%	15.1%	411	0.453
	No	38.5%	45.2%	16.3%	1,472	
Weekly exercise	Low	31.9%	39.8%	28.3%	332	0.000
	Moderate	38.6%	45.2%	16.3%	682	
	High	42.3%	47.0%	10.7%	844	
Finance problems	No	39.7%	44.6%	15.7%	1,546	0.551
	Yes	36.7%	46.0%	17.3%	335	
Education		14.9 (1.98)	14.8 (1.94)	14.3 (2.08)	1,883	0.000
Work hours		44.0 (12.13)	46.0 (12.22)	47.4 (13.71)	1,836	0.025
Rand-MHC		49.8 (8.60)	48.5 (8.95)	49.3 (8.69)	1,866	0.584
Rand-PHC		52.9 (6.23)	52.2 (6.29)	50.2 (6.87)	1,851	0.000

Notes. Proportions and chi-square tests are reported for categorical variables, whilst means and standard deviations and the significance of ANOVA tests are presented for continuous variables. This table includes data from all employed participants at wave two who had data on job characteristics excluding those whose BMI >50 (n=6). The numbers included in the final analyses were slightly lower based on complete cases analyses (e.g., final analysis n=1,774 males and n=1,745 females).

Table 3.6*Descriptive Statistics for Females by Normal Weight, Overweight, and Obesity*

		Normal weight	Overweight	Obese	N	Sig.
Age group	20	67.8%	19.2%	13.0%	851	0.000
	40	50.4%	26.9%	22.7%	1,000	
Employment	FT	59.1%	22.6%	18.4%	1,379	0.385
	PT	56.4%	25.6%	18.0%	472	
Children	Yes	50.8%	26.8%	22.5%	1,046	0.000
	No	68.3%	18.9%	12.8%	805	
Current smoker	Yes	58.3%	22.6%	19.1%	367	0.000
	No	68.3%	18.9%	12.8%	1,484	
Weekly exercise	Low	48.1%	26.3%	25.6%	555	0.000
	Moderate	57.0%	24.3%	18.7%	753	
	High	72.0%	18.6%	9.3%	515	
Finance problems	No	59.7%	22.8%	17.5%	1,475	0.057
	Yes	53.1%	25.5%	21.5%	373	
Education		15.1 (1.90)	14.7 (2.06)	14.2 (2.01)	1,850	0.000
Work hours		38.4 (12.54)	38.2 (12.42)	38.8 (13.6)	1,800	0.813
Rand-MHC		48.1 (9.35)	48.1 (9.35)	46.5 (9.82)	1,841	0.022
Rand-PHC		52.3 (6.81)	50.9 (7.16)	47.7 (8.93)	1,833	0.000

Notes. Proportions and chi-square tests are reported for categorical variables, whilst means and standard deviations and the significance of ANOVA tests are presented for continuous variables. This table includes data from all employed participants at wave two who had data on job characteristics, excluding those whose BMI >50 (n=6). The numbers included in the final analyses were slightly lower based on complete cases analyses (e.g., final analysis n=1,774 males and n=1,745 females).

3.5.2 Multinomial Logistic Regressions

3.5.2.1 Job Strain

Two models were run using job strain as a predictor variable for overweight and obesity compared with normal weight controls: the first was a univariate model and the second included covariates. Table 3.7 shows that in model A, where job strain was entered as the sole predictor, there was no significant change in the likelihood of being overweight or obese relative to normal weight controls who had not reported job strain. This result held for both males and females. Table 3.7 shows that this was also the case when covariates were added (model B). For males, being in the 40s age group was significantly associated with increased odds for overweight and obesity, but for females, being older was only associated with increased odds of obesity. Not

having children was significantly associated with decreased odds for overweight and obesity among males and females. For males, increased job hours were modestly, although significantly, associated with overweight and obesity, and this modest association was also observed with obesity among females. Increased physical health was modestly and significantly associated with decreased odds for overweight and obesity among females, and with decreased odds for obesity among males. A higher number of years of education was associated with decreased odds of overweight and obesity for males and females, although the size of the association was larger for females and increased with obesity. Moderate exercise levels were associated with decreased odds for overweight in females only, although vigorous exercise was associated with decreased odds of obesity for males and females.

The univariate and multivariate analyses were replicated using low job control and high job demands as key predictors of overweight and obesity. In the univariate analyses, low job control was associated with significantly decreased odds of overweight and obesity for males (OR overweight: .81, 95CI: .66–1.00; OR obesity: .72, 95CI: .54–.96), although further investigations found that this was an artefact of the age group difference and was attenuated in the multivariate models (OR overweight: .94, 95CI: .73–1.14; OR obesity: .86, 95CI: .62–1.17). Thus, no association was evident from the analyses using low job control and high job demands to predict overweight and obesity among males or females (the results are reported in Appendix D).

Table 3.7

Univariate and Multivariate Multinomial Regression Models Predicting Overweight and Obesity from Job Strain in Males and Females

Model A		RRR Ov.	P	95% CI		RRR Ob.	P	95% CI	
Males	Job strain	0.94	.632	1.22	0.72	0.86	0.595	1.25	0.60
Females	Job strain	1.08	.589	1.43	0.82	1.21	0.204	1.64	0.90
Model B		RRR Ov.	P	95% CI		RRR Ob.	P	95% CI	
Males	Job strain	0.95	0.702	0.72	1.25	0.85	0.436	0.58	1.27
	Age group (40s)	1.43	0.018	1.06	1.93	1.83	0.004	1.21	2.77
	Smoke (No)	1.06	0.694	0.81	1.38	1.16	0.436	0.80	1.69
	Children (No)	0.59	0.000	0.44	0.78	0.61	0.015	0.41	0.91
	Exercise (Moderate)	1.00	0.982	0.72	1.37	0.54	0.001	0.37	0.79
	Exercise (Vigorous)	1.14	0.433	0.83	1.56	0.42	0.000	0.28	0.63
	Finance prob. (Yes)	1.07	0.639	0.80	1.43	0.92	0.667	0.62	1.36
	Mental health	0.99	0.396	0.98	1.01	1.00	0.921	0.98	1.02
	Physical health	0.99	0.256	0.97	1.01	0.96	0.000	0.93	0.98
	Education	0.95	0.085	0.90	1.01	0.87	0.000	0.80	0.94
	Job hours	1.01	0.015	1.00	1.02	1.02	0.006	1.00	1.03
	Constant.	3.57	0.064	0.93	13.77	23.37	0.000	4.07	134.30
Females	Job strain	1.11	0.492	0.83	1.49	1.13	0.455	0.82	1.57
	Age group (40s)	1.37	0.081	0.96	1.95	1.44	0.072	0.97	2.14
	Smoke (No)	1.13	0.460	0.82	1.54	1.28	0.164	0.90	1.82
	Children (No)	0.70	0.049	0.49	1.00	0.67	0.055	0.45	1.01
	Exercise (Moderate)	0.81	0.142	0.61	1.07	0.70	0.019	0.52	0.94
	Exercise (Vigorous)	0.60	0.003	0.43	0.84	0.39	0.000	0.26	0.57
	Finance prob. (Yes)	1.18	0.295	0.87	1.59	1.16	0.373	0.83	1.62
	Mental health	1.01	0.462	0.99	1.02	1.00	0.566	0.99	1.02
	Physical health	0.97	0.006	0.96	0.99	0.93	0.000	0.91	0.95
	Education	0.93	0.029	0.88	0.99	0.83	0.000	0.78	0.89
	Job hours	1.01	0.061	1.00	1.02	1.02	0.000	1.01	1.03
	Constant.	2.54	0.173	0.66	9.70	60.38	0.000	14.61	249.62

Notes. Reference category for BMI dependent variable is normal weight. Model A: job strain; model B: job strain with covariates. Ov. = overweight, Ob. = obesity.

3.5.3 Multiple Linear Regressions

3.5.3.1 *Job Strain*

The relationship between the categorical job strain variable was also modelled with continuous BMI in two multiple regression models (model A as the univariate analyses and model B including covariates in Table 3.7). For males and females, no association was observed between job strain and BMI in models A and B. For males and females, there was a positive significant association between being older (in the 40s age group) and job hours with BMI, and for males who did not smoke. There was a negative significant association between BMI and not having children, moderate and vigorous exercise levels, physical health scores, and years of education for males and females.

The univariate and multivariate regression analyses were repeated with low job control and high job demands predicting BMI. No association among high job demands (univariate analyses B: .39, $p=.118$, 95CI: $-.10$ to $.89$) and low job control (B: .24, $p=.347$, 95CI: $-.26$ to $.73$) was found for females in the univariate or multivariate analyses (reported in full in Appendix D). For males, no association was found among high job demands and BMI in the univariate (B: .25, $p=.201$, 95CI: $-.13$ to $.62$) or multivariate analyses, although in the univariate analyses, job control was associated with BMI (B: $-.44$, $p=.02$, 95CI: $-.82$ to $-.06$), which was attenuated with the inclusion of the age group predictor in the multivariate analyses (B: $-.14$, $p=.480$, 95CI: $-.532$ to $.250$; reported in full in Appendix D).

Table 3.8

Linear Regression Models Examining the Association of Job Strain with BMI in Males and Females

Model A		B	P	95% CI	
Males	Job strain	−0.10	0.682	−0.59	0.39
Females	Job strain	0.54	0.074	−0.05	1.14
Model B		B	P	95% CI	
Males	Job strain	−0.10	0.670	−0.59	0.38
	Age group (40s)	1.13	0.000	0.62	1.65
	Smoke (No)	0.47	0.048	0.00	0.94
	Children (No)	−0.47	0.067	−0.97	0.03
	Exercise (Moderate)	−1.01	0.000	−1.53	−0.48
	Exercise (Vigorous)	−1.00	0.000	−1.53	−0.47
	Finance prob. (Yes)	0.14	0.590	−0.36	0.63
	Mental health	0.00	0.883	−0.02	0.03
	Physical health	−0.07	0.000	−0.10	−0.04
	Education	−0.20	0.000	−0.30	−0.10
	Job hours	0.02	0.002	0.01	0.04
	Constant.	32.03	0.000	29.78	34.28
Females	Job strain	0.36	0.213	−0.21	0.93
	Age group (40s)	1.08	0.002	0.39	1.77
	Smoke (No)	0.46	0.136	−0.14	1.06
	Children (No)	−0.87	0.016	−1.57	−0.16
	Exercise (Moderate)	−0.65	0.021	−1.20	−0.10
	Exercise (Vigorous)	−1.37	0.000	−2.00	−0.73
	Finance prob. (Yes)	0.35	0.251	−0.25	0.94
	Mental health	0.02	0.276	−0.01	0.04
	Physical health	−0.17	0.000	−0.20	−0.13
	Education	−0.30	0.000	−0.42	−0.17
	Job hours	0.04	0.00	0.02	0.06
	Constant.	36.16	0.00	33.62	38.70

Note. Model A = job strain only; model B = job strain and covariates.

3.6 Discussion

This study adds to the literature investigating the potential relationship between job strain and BMI. It found no evidence that job strain is directly associated with BMI outcomes.

Specifically, for the overweight and obese BMI categories, no support for the hypothesis that job strain is associated with a greater likelihood of being either overweight or obese was found in the multinomial logistic regression analyses. The relationship between job strain and BMI outcomes was also tested in linear regression analyses modelling BMI as a continuous dependent variable, with no evidence found that job strain is associated with BMI for males or females.

Given differences in the literature testing job strain and its components (see Tables 3.1 and 3.2), the logistic and linear regression models were repeated to investigate high job demands and low job control for a relationship with BMI, overweight, and obesity. Neither provided any supporting evidence for an association (the results of the analyses are available in Appendix D).

3.6.1 Comparisons with the Prior Literature

The null findings reported here are in line with both the earlier review conducted by Overgaard et al. (2004) and the more recent systematic review by Solovieva et al. (2013), each of which concluded that there was little evidence in the cross-sectional literature for an association between job strain and obesity. The null findings are supported by the results of other studies (e.g., Ishizaki et al., 2004; Lallukka et al., 2008), which were included in the reviews by Overgaard et al. (2004) and Solovieva et al. (2013), and contributed to the reviews' conclusions. Despite focusing on obesity, each review included studies analysing both obesity and continuous BMI as the outcome variable. Thus, while they did not distinguish and discuss the two types of research, the null findings reported here for both continuous and categorical BMI are in line with their broad conclusions.

The results of modelling BMI categorically here are in line with the results of Lallukka et al. (2008), who used logistic regression to estimate the odds of obesity among employees reporting job strain from Helsinki, London, and Japan. Similar to the present study, the three datasets analysed by Lallukka et al. were generally large, and the analyses were performed stratified by sex to remove further confounds. Across the three studies analysed, the estimated odds for obesity ranged from a 16% reduction in odds to a 37% increase (OR .84–1.37) for males, and a 9% reduction in odds to a 67% increase for females (OR .91–1.67). These odds were significantly different from the odds of obesity estimated for the employees reporting low strain. In the present results, the estimated odds for obesity were more conservative at a 15%

reduction in odds for males (model B OR .85) and a 13% increase for females (model B OR 1.13).

In their analyses, Lallukka et al. contrasted the odds for obesity against all other BMI levels (normal weight and overweight combined). Combining the reference category in this way can present a confound for the comparison of risk because health risks associated with obesity do not always correspond directly with the chosen category cut-points (Stevens et al., 2006; WHO, 2013). Few studies have explicitly considered or modelled the overweight BMI category, with more studies focusing on obesity. The present results extend those of Lallukka et al. by modelling the odds ratios for overweight males and females in addition to those in the obese category. No evidence was found that reporting job strain was associated with increased odds of either overweight or obesity. Thus, across these four large datasets (i.e., Lallukka et al. and the present investigations) sampled from four nationalities, no evidence was found for an association of job strain with overweight or obesity for either males or females.

3.6.2 Comparisons with Prior Continuous Literature

An advantage of the current study is that it models BMI categorically and continuously. While overweight and obesity are categorised based on the continuous BMI distribution, and thus analyses of each are related, different information is generated by testing each. There are health risks and protective factors that may demonstrate largely uniform associations across the BMI distribution (i.e., salt intake, sedentary v. active lifestyle; Rodgers et al., 2004; Ross & Bradshaw, 2009), while others may have stronger, or exclusive, associations with differing BMI categories (e.g., the association of diabetes and obesity), hence the utility of BMI categories. Taken together, the results can provide a more complete picture of an association of job strain with BMI outcomes. Further, there are inconsistencies present among various studies analysing either a continuous or a categorical BMI. Without simultaneously modelling both, this would present another confound within the literature.

In agreement with the results of modelling BMI categorically, no evidence supporting a relationship of job strain with continuous BMI was found in the current analyses. This finding is supported by others that have modelled BMI continuously. Jonsson et al. (1999) analysed Swedish employees using ANOVA to investigate whether BMI differed among those reporting job strain when compared with males and females not reporting job strain (Jonsson et al., 1999). In sex-stratified ANOVAs, no significant differences were found among the groups. BMI was reported to differ by .36 BMI units in 746 males and by .15 BMI units in 872 females. These small average differences are consistent with the present analyses of Australian employees, whereby job strain was estimated to be associated with an average difference of $-.10$ and $.36$ BMI units for males and females, respectively, that were not statistically significantly different from the BMI of those without job strain. Further, the lack of evidence for an association with continuous BMI is consistent with other research investigating an association of job strain with BMI in Australian employees, which, until the present study, had only been modelled continuously (Ostry et al., 2006).

3.6.3 Job Strain and BMI in Australia

The current findings contribute to knowledge regarding job strain and BMI using Australian data. To date, only two other studies have used Australian data to model the relationship of job strain, demands, and control with BMI. First, Ostry et al. (2006) conducted a telephone survey regarding working conditions among a representative sample of the Victorian working population and found no evidence for an association of job strain with BMI in analyses of males and females. This is the only other Australian study (in addition to the analyses reported here) to analyse an association of job strain with BMI using Australian data. Both Ostry et al. and the current study agree, finding no evidence for an association. However, Ostry et al. also analysed the subscale components—job demands and control—and found evidence that BMI was almost one unit higher for males who reported high job demands than for males who

reported low job demands. This pattern is somewhat reminiscent of that reported by Jonsson et al. (1999), who also reported an almost one-unit BMI difference for employees reporting high job demands despite not finding a significant association with job strain. Despite the similarities, the pattern does not show consistent evidence for a reliable association because the findings of each study were reported for male Australian employees and female Swedish employees.

In the second existing Australian study, Bean et al. (2015) used data from participants from South Australia to analyse associations between job demands and continuous BMI, and found no evidence for an association in univariate or multivariate analyses. The null results of testing an association of high job demands with BMI in the present analyses (see Appendix D) are in line with these earlier findings. Thus, across three studies testing an association of high job demands with BMI using Australian data, only one study reported finding evidence of an association.

The evidence for an association of job control with BMI in Australian data is similarly lacking. Ostry et al. and the present analyses (reported in Appendix D) found no evidence for an association of low job control with BMI. However, Bean et al. found that the components of job control, skill discretion, and decision authority were associated with BMI in multiple regression analyses. They observed a nonsignificant positive relationship between decision authority and BMI, and a significant negative relationship between skill discretion and BMI: an increase in skill discretion was estimated to have a -0.163 decrease in BMI. Notably, the same pattern of results was found when they analysed the same models using waist circumference in place of BMI. However, when analysing waist circumference, both relationships were statistically significant: a negative relationship between skill discretion and decreased waist circumference, and a positive relationship between decision authority and increased waist circumference. While the size of the relationship between decision authority and BMI was estimated at just $.087$ BMI units for every unit increase in decision authority (which was modelled continuously) and was

reported as marginally significant ($p=.075$), the results of the concurrent analyses with waist circumference increased the authors' confidence in the relationship.

Because Bean et al. modelled the subscales of job control individually, it is difficult to directly contrast their findings with other studies. It is possible that the standard construction of job control may mask opposing relationships of skill discretion and decision authority with BMI and obesity, possibly contributing to the inconsistent results in the literature (Bean et al., 2015). Further critical analysis of the sample size of their study shows that it is also the smallest Australian study, with just 450 participants analysed. The current study reported in this chapter is the largest Australian study to date, affording the analyses more power and minimising the possibility of spurious type one errors. While it is possible that further research that models the JDC subscales continuously and analyse the subscales of job control may influence the results of testing an association with BMI, the current evidence for an association among Australian employees is lacking.

3.6.4 Current Findings in the Context of Previous Evidence

The null findings of the current study, although supported by the conclusions of other reviews and high-quality studies, do not unequivocally clarify the question of whether job strain is associated with BMI. While a critical appraisal of the evidence in the prior literature raises doubt of an association, there remain inconsistent results in the literature (as described in the introduction); thus, job strain and BMI in association together should be further investigated. For instance, similar to the current study, Fernandez et al. (2010) opted to model the association of job strain with BMI both categorically and continuously. The characteristics of their sample were closely aligned with the current sample, with each study analysing mid-life adults who were generally well paid and highly educated. Fernandez et al. reported an increase of almost one BMI unit for employees who were experiencing job strain compared with those without job strain, and they found that job strain predicted a 45% increased risk for overweight and obesity.

These associations were found not only in the univariate analyses, but also in analyses adjusted for measures of income, education, smoking, sex, and race. However, even in the univariate analyses here, no evidence was found for an association of job strain with BMI.

Although the association reported by Fernandez et al. was robust to many covariates, their results suggest that this relationship can likely be explained by exercise and sedentary behaviour (TV viewing hours). The stepped analysis method used by Fernandez et al. supports this reasoning: after adjusting for exercise and TV viewing hours, they reported no association of job strain with BMI or overweight and obesity. However, while exercise and TV viewing may have accounted for the relationship found by Fernandez et al., others who similarly found support for an association found that the results were robust to adjustment for similar lifestyle variables.

For example, Kouvonen et al.'s (2005) study of 45,810 Finnish public sector employees was the second largest to date and found that job strain was positively associated with higher BMI for males and females. They reported evidence for a relationship between job strain and higher continuous BMI in models adjusted for sex, age, SES, marital status, and job contract. In repeated analyses further adjusted for lifestyle variables, including current smoking, alcohol consumption, and LTPA, they found that the size of the relationship was smaller, but these variables did not explain the full relationship between job strain and BMI in their sample. However, while TV viewing hours are inversely related to higher LTPA (Matthews et al., 2018), Kouvonen et al. did not specifically account for this. While it is possible that accounting for TV viewing hours may nullify the relationship found by Kouvonen et al., these differing results suggest that further research is needed to clarify the role of covariates in the relationship of job strain and BMI.

Kouvonen et al.'s analyses support continued investigations to clarify the association of job strain with BMI. Their finding of a weak (but statistically significant) effect is consistent

with the results of the largest cross-sectional study to analyse job strain and overweight and obesity to date. Nyberg et al. analysed over 160,000 individuals, which gave the analysis greater power than previous studies. The size of the association described by Nyberg et al. was an increase of 7% and 14% in the odds for job strain among obese class 1, and classes 2 and 3 combined, respectively. While these estimates were statistically significant, they were smaller than those described in other studies, even by those who reported no statistical evidence for an association (i.e., Lallukka et al., 2008, reported an increase in odds as high as 67% for obesity among those with job strain, although this was not significant). This shows that there are factors beyond statistical significance thresholds to be considered when determining the strength of evidence for associations (Cortina & Landis, 2010; Wasserstein & Lazar, 2016), including the broader context of the nature of the variables, findings within the existing literature, and sample size and power considerations.

3.6.4.1 Power Considerations

Previous studies that have found a positive relationship between job strain and BMI outcomes and overweight and obesity have described the size of the effect as small and weak (i.e., Bean et al., 2015; Kouvonen et al., 2005; Nyberg et al., 2012; Overgaard et al., 2004). When an effect is expected to be small, it is important to consider the power of a study to detect such an effect (Cortina et al., in Lance & Vandenberg, 2010). Because population-based epidemiological datasets usually contain large sample sizes to approximate populations, they are often considered to be powered adequately; however, this may not always be the case. In attempting to explain the differences between the significance of the results of Lallukka et al. and Nyberg et al., the sample sizes between the two studies differed notably (Nyberg et al. analysed approximately 160,000 individuals, while Lallukka et al. analysed samples ranging from 307 to 4,667 participants). Thus, it is possible that the analyses conducted by Lallukka et al. were underpowered and that the large sample size analysed by Nyberg et al. increased the

power of the analyses to detect a statistically significant, though weak, association between job strain and BMI.

Consistent with this, Overgaard et al. (2004) noted in their review of the literature that a number of the smaller studies reviewed may have been underpowered. Further, reviews by Solovieva et al. (2013) and Wardle et al. (2012) summarising research on stress and adiposity (including a specific focus on work stress and BMI outcomes) concluded that studies with higher-quality methodologies were more likely to report an association than those deemed lower in quality. Thus, there is some tension between concluding whether there is a weak relationship between job strain and BMI that is difficult to detect or, alternatively, that there is no direct association between job strain and BMI outcomes. It is plausible that smaller studies have not had the power to reliably detect an association, and thus it has only been detected by chance in certain studies. **Whilst the methodological approach here is of high-quality, the present sample sizes analysed are in line with those of Lallukka et al. and other, more average, epidemiological studies in this area. Thus, without further analysis, this is not a consideration that is able to be elucidated with the current sample sizes.**

3.6.5 Change in Job Strain and BMI Over Time: The Need for Longitudinal Studies

A number of issues raised throughout this cross-sectional analysis chapter, and in other evidence in the literature, point to the benefits of progressing beyond cross-sectional research to examine a potential association between job strain and BMI over time. First, inconsistencies in the results of the cross-sectional studies suggest that there may be measurement issues and inadequacies in the sample sizes that could be addressed with more powerful, targeted longitudinal data analyses. Not only do some cross-sectional studies report evidence of an association and others report null findings, but there are significant findings in studies for both positive and negative relationships (e.g., Kivimäki et al., 2006; Nyberg et al., 2012).

In seeking to understand the inconsistencies in the literature, the complex and cumulative nature of BMI is not often considered—BMI as an indicator of adiposity represents a dynamic phenomenon that changes over time. While BMI as a proxy measure for excess fat has demonstrated acceptable validity (Bouchard, 2007; Flegal & Shepherd, 2009), including in the self-report format (Flood et al., 2000), overweight and obesity are highly multifaceted individual constructs, and not all variables affect BMI in a consistent way across people. Individual BMI is determined by a range of factors including genetic, behavioural, social, and psychological domains (Balaskas et al., 2017). Factors that may influence one individual's BMI to increase may not affect another's BMI at all, or may even affect another's BMI in an opposing manner (i.e., BMI decrease). These patterns are likely better captured in longitudinal studies that have multiple BMI assessments over time.

Kouvonen et al. (2005) noted that the weak and inconsistent pattern of results reported in the relevant literature may, in part, be confounded by not accounting for individual-level differences. Individual differences in response to stress are well documented in the stress literature (Greeno & Wing, 1994; Ogden et al., 2009); thus, they may be important in considering whether job strain is associated with overweight and obesity. As an example of the complexity of individual variation in BMI, there is evidence that some may lose weight, while others gain weight, in response to experiencing job strain (Kivimäki et al., 2006; Nyberg et al., 2012). In operationalising this possibility in research studies, some researchers have explored whether the association between job strain and BMI over time may depend on higher or lower initial BMI at the study baseline (baseline BMI) (Kivimäki et al., 2006; Nyberg et al., 2012).

Given the evidence outlined above indicating that the size of the relationship between job strain and BMI (if present) is likely to be small, and the importance of considering individual-level variance in BMI over time, it appears that longitudinal analyses of job strain and BMI over time are needed. Longitudinal analysis methods can help address and explore individual variance

in BMI (better fitting the nature of BMI), and can assist with power and sensitivity by providing multiple observations per individual. Given that BMI levels are dynamic states, with associations and effects of stress manifesting over time, the observation of job strain and BMI over time may assist in clarifying some of the reported inconsistencies in the cross-sectional literature.

3.6.6 Limitations

Many of the limitations relevant to this chapter (e.g., self-report BMI, unmeasured variables, and unexplored pathways) are also relevant to other sections in this thesis and are therefore covered in detail in Chapter 7, the concluding discussion chapter of the thesis. However, there are important limitations to the current cross-sectional analysis chapter that should be noted. First, although a larger sample was analysed than in other Australian studies, the limited sample size in the current analyses is important to note, especially when set against the context of other studies with larger sample sizes (i.e., Kouvonen et al., 2005; Nyberg et al., 2012). Second, restricting the age of the sample to two narrow age cohorts (24–28 and 44–48) has both strengths and limitations. The younger age group may be yet to experience significant job strain, thus limiting the strength of the findings. Further, the findings for these age groups cannot be transferred to other age groups (e.g., those in their 30s or 50s).

The use of cross-sectional data only in this chapter is an important limitation because the relationship between job strain and BMI may be more thoroughly examined with the use of longitudinal analysis measures. Overweight and obese BMI levels develop as a result of the process of weight gain over time, and the main theoretical reason for expecting a relationship between overweight and obesity and job strain is the notion that job strain may directly or indirectly (through health behaviours and biological processes) be associated with weight gain, culminating in the observed BMI outcome, including overweight and obesity (Azagba & Sharaf, 2012). While one would thus expect to see an association between overweight and obesity and

job strain at any point in time when sampled cross-sectionally, given the small size of the effect expected, there may be too much noise and error contained within many cross-sectional datasets. It may be more direct and precise to observe and measure the theoretical mechanism—variation in BMI in association with job strain—within a longitudinal dataset. Such a dataset would provide the ability to observe change in BMI over time and reduce the influence of other individual differences (either stable or varying over time). Consistent with this, the remaining chapters in this thesis use longitudinal data on both job strain and BMI to begin investigating the relationship over time.

3.7 Chapter Conclusions

The results from the analyses in this chapter suggest that it is unlikely that there is an association between job strain and BMI, including both across the distribution of BMI and with overweight and obese BMI categories. However, it is plausible that individual-level variation that contributes to the multifaceted nature of BMI, including the potential for differential associations of job strain on BMI, may have masked an association. Further, methodological inconsistencies, and the possibility that an association between job strain and BMI outcomes is weak at best, may have obscured a potential association in the current study and in previous studies. While the concurrent modelling of both categorical and continuous BMI is a strength, as is the additional research in the Australian context, further longitudinal analyses may help to further clarify and examine any potential association between job strain and BMI outcomes.

Chapter 4: Is There an Association Between Job Strain and BMI Outcomes Over Time? Investigating Longitudinal Associations

4.1 Chapter Summary

This chapter extrapolates on the previous chapter, which reviewed the cross-sectional literature and identified the need for an examination of job strain with BMI outcomes over time. That need is addressed in this chapter, which presents the results of one of the first longitudinal investigations of an association of job strain with BMI in an Australian sample.

The literature review in this chapter begins by stating the importance of longitudinal investigations over time and then describes reasons to include BMI as a continuous variable over time in longitudinal analyses. In doing so, the benefits of studying modest change in BMI as a potential indicator for health risks are discussed, as well as how a focus on shifting between categories of BMI (e.g., into obesity) over time can limit investigations.

Subsequently, the small body of literature on job strain and BMI outcomes over time is reviewed, and related conceptual and analytic issues are identified throughout: specifically, the examination of more modest BMI change over time, the use of appropriate analytic techniques, the importance of the length of follow-up, the importance of multiple data points to examine changes over time (i.e., beyond one measurement of change), and the separation of sex in analyses. This review lays the foundation for the main research question in this chapter: Is there an association between job strain and BMI over time?

Aims: The main aim of the current chapter is to use the PATH dataset to concurrently test four different models that explore the possibility of a relationship between job strain and BMI over time.

Methods and participants: Data collected at waves one to four from the 40s age cohort of the PATH Through Life longitudinal survey were used in the current analyses. The inclusion criteria were that participants were in the 40s age cohort, responded as being employed either full-time or part-time, and had information on the JDC scales. This resulted in 1,130 males and 1,141 females who met the criteria at wave one, 1,030 males and 1,076 females at wave two, 976 males and 1,021 females at wave three, and 700 males and 745 females at wave four.

Statistical analyses: The association between job strain and continuous BMI over the four waves of data was modelled in four sets of MLMs. A univariate model (model A) and a fully adjusted model (including relevant covariates, model B) were analysed for each set of MLMs, and each analysis was conducted stratified by sex.

Results: No evidence was found for an association between job strain and BMI over time across any of the four sets of MLMs, in either the univariate or adjusted analyses, for males and females.

Discussion and conclusions: Multilevel modelling analytic techniques were used to model the longitudinal data, thereby improving the power and specificity of the model and reducing the bias of the estimates calculated. While this is not the first study in the job strain and BMI literature to use such analytic methods, the results agree with the two prior studies that have also used MLM random and fixed effects analyses—that is, no association was evident between job strain and BMI over time. Given that previous research identifying a positive, statistically significant association between job strain and BMI has only identified very small effects, the current null findings are in line with previous suggestions that job strain may not be an important target for any potential modification of increasing BMI trends.

4.2 Introduction and Background

4.2.1 The Need for Longitudinal Research When Investigating BMI

The previous chapter reviewed the cross-sectional body of research on job strain and BMI outcomes, including overweight and obesity. It highlighted the inconsistent state of findings, alongside conceptual (i.e., the continuous nature of BMI and adiposity) and analytical (e.g., the small effect size anticipated) challenges. The need for longitudinal research is crucial in further attempting to clarify whether an association between job strain and BMI outcomes exists. Other researchers have also stated that longitudinal research is a suitable next step (i.e., Azagba & Sharaf, 2012; Bean et al., 2015; Kouvonen et al., 2005; Overgaard et al., 2004). Recommendations to examine job strain and BMI longitudinally across time reflect that longitudinal data may be more sensitive to the nature of any such relationship. Longitudinal data and models allow for the examination of within-person change over time. Thus, they often have greater sensitivity and statistical power than cross-sectional analyses (Khoo et al., 2005; Singer & Willet, 2003; Tabachnick & Fidell, 2007), and also offer greater flexibility and depth to investigate different aspects of, and influences on, the relationship between job strain and BMI.

The study of change in BMI over time requires moving past the predominant practice of examining cross-sectional data in favour of analysing longitudinal datasets that can explore change over time to offer insights such as whether there is any covariation of job strain and BMI, or temporal precedence—Does one occur before the other? Such insights may contribute to evidence for a causal relationship. Further, the increased sensitivity of longitudinal data and analysis methods is a better fit for the highly multifactorial nature of BMI. Research suggests that many modest effects collectively contribute to BMI variation rather than a smaller number of dominant effects (Lovasi et al., 2012; Sund et al., 2010); thus, analysis techniques and methods that are sensitive enough to detect weak effects are required. To this end, longitudinal

data and analytical methods offer several advantages in examining the association between job strain and BMI beyond cross-sectional methods.

4.2.1.1 Examining Change in BMI Over Time Using a Continuous Outcome

Research on BMI over time demonstrates that BMI is a dynamic, individual, and varied process that cannot be adequately understood with cross-sectional research alone and without acknowledging that BMI and weight gain occur across a continuum. While the examination of overweight and obesity categories (however they are defined or labelled) is both useful and important, it can promote an understanding of BMI status as an almost static state rather than the study of an underlying dynamic biological phenomenon. Here and in epidemiological datasets generally, BMI specifically represents levels of adiposity that are able to vary over time (Nuttall, 2015). In Chapter 3 (the cross-sectional chapter), an argument was made for the examination of BMI continuously; however, in the current chapter, where change over time is the focus, this argument is advanced from the examination of the distribution of BMI in full to the examination of *changes* across the full distribution that are not limited by changes across imposed thresholds (i.e., categories of BMI).

There are numerous reasons why studying change across the BMI distribution may yield further insights into the factors that contribute to increasingly risky BMIs, including overweight and obese BMIs. The foremost of these reasons concerns the greater sensitivity to detect modest effects (Khoo et al., 2005; Singer & Willet, 2003; Tabachnick & Fidell, 2007). For example, categorisation of underlying continuous variables leads to information loss, and maintaining this information can increase the power of analyses (Altman & Royston, 2006; Bennette & Vickers, 2012; Kivimäki et al., 2006). While the selection of thresholds and categories is beneficial for purposes such as interpretation, science and health communications, and policy targets, this chapter maintains that there are further benefits to be gained from investigating change in BMI, because the analysis of BMI categories alone may not be sensitive enough to detect modest

associations with job strain (particularly given the multifactorial nature of BMI and that the effect, if any, is likely to be small).

4.2.2 BMI Change Across Broad Categories

Researchers and health professionals often employ categories of BMI to operationalise individuals' adiposity levels, because categories of BMI are recognised as a simple and universal tool for standardising an individual's weight (due to excess adiposity) and health risks (WHO, 2000). However, some consider that the use of broad categories—in particular, WHO-defined BMI categories—is too broad to correspond meaningfully or sensitively to increases in risk for morbidity and mortality (Lohse et al., 2017; Nuttall, 2015; Strommel & Schoenborn, 2010). Transitioning across BMI categories places a focus on the strongest or most powerful of associations, narrowing the focus of research to the specified thresholds. While this is important to identify the strongest risk and protective factors, unless an individual is close to a specified threshold, they must gain or lose a substantial amount of weight before shifting between categories occurs (Preston et al., 2015).

To highlight this, Table 4.1 displays a normal-weight individual with a baseline BMI of 21.1 and the subsequent weight gain required to shift the individual into the overweight and obese BMI categories. As shown, starting at a normal weight of 61 kg, the individual would need to gain 12.2 kg to shift into another category. To put this increase into perspective, this is a 20% increase in body weight, or an increase of one-fifth of the individual's starting body weight to shift from the normal weight category to the overweight BMI category. The gain in body mass further increases when considering the individual's shift to the obese category: a 43% increase in body weight, or a 26.0 kg gain, would be required for a shift into the obese category.

Table 4.1

How Much a 170 cm Tall Person Would Have to Gain in Kilograms and Body Weight

Percentage to Move Out of the Healthy BMI Category into the Overweight/Obese BMI

Categories

Height (cm)	Weight (kg)	BMI	BMI category	Gain (kg)	Gain (%)	Gain (kg)	Gain (%)	Gain (kg)	Gain (%)
170 cm	61.0	21.1	Healthy/normal	Baseline	0%				
170 cm	64.1	22.2	Healthy/normal	3.1	5%				
170 cm	67.1	23.2	Healthy/normal	6.1	10%				
170 cm	70.1	24.3	Healthy/normal	9.1	15%	Baseline	0%		
170 cm	73.2	25.1	Overweight	12.2	20%	3.1	4%	Baseline	0%
170 cm	87.0	30.1	Obese	26.0	43%	16.9	24%	13.8	24%

Of course, the weight gain needed to shift categories depends on the individual's starting BMI and height. If the individual's BMI is 24.3 when measured at baseline, a 3.1 kg gain (4% increase) would be required to shift into the overweight category, and a 16.9 kg gain (24% increase) to shift into the obese category. Those with a BMI close to a category threshold would have to gain a smaller amount to shift categories, and in research examining shifts between categories, it is likely that these individuals would be highlighted in the analyses. However, despite this, for individuals in the bottom three-quarters of the normal weight category (BMI 18.5–23.3), a weight gain of *at least* 6 kg would be required to shift them into the overweight category. Further, these individuals would be required to gain a *minimum* of 19.8 kg to reach the cut-off for the obese category (BMI 30.0). However, taking a BMI of 25.1 as the baseline value, these individuals would still be required to gain 19% of their starting weight prior to an upward category shift from overweight to obesity. The amount of weight gain required to shift BMI categories is somewhat misaligned with the fact that, on average, healthy individuals who are free of chronic disease only gain around one-third to half of a kilogram per year across their lifespan (Mozaffarian et al., 2011).

Further, evidence suggests that age is a contextual factor that influences average yearly weight and BMI gain, making the rate of increase slower in mid-life than in younger adults. In a longitudinal Australian population-based sample with a mean age of 49, Peeters et al. (2014) found that the average rate of annual weight gain varied as the sample aged, decreasing from an average gain of .34 kg per year in the first five-year period to just .13 kg per year in the second six-year period. Given that the relationship between weight and BMI is linear once height is fixed (as considered in adulthood), this same pattern was reflected in the results of Hayes et al. (2015) when analysing BMI explicitly. They also used Australian data and found that the annual average increase in BMI decreased, and that the rate of decrease depended on increasing age. This highlights the slow rate of increase annually and is consistent with other research showing that weight gain is highest among young adults in both Australia and other countries (Peeters et al., 2014). Further, while weight and BMI increase are highest among younger adults, as weight typically accumulates over time, rates of overweight and obesity are highest among mid-life adults (Aarestrup et al., 2016; Zheng et al., 2017). Thus, for most individuals, weight gain and BMI increase is a phenomenon that changes in modest amounts over time, but has the potential to accumulate to detrimental levels.

The slow rate of expected weight gain (and thus BMI increase) has implications for longitudinal research design, particularly when considering the power of a study to detect effects on, and associations with, BMI change. For example, using a liberal estimate of annualised weight gain at .5 kg per year, and knowing that (for most individuals within a category) a 6 kg increase is the minimum to observe a BMI category shift (as per the 170 cm height example above), it may be expected to take approximately 12 years to observe the average 6 kg increase. While the weight gain required to shift BMI depends on height, the average annual weight gain that drives BMI change over time is slow, especially in mid-life. This implies that the length of time for follow-up is another important factor to consider in examining BMI outcomes over

time, even for variables that may be associated with a faster rate of average BMI increase (i.e., stress).

4.2.2.1 Summary of the Use of Categorical Thresholds and the Context of Follow-Up Lengths in the Longitudinal Job Strain and BMI Literature

In longitudinal research on job strain and BMI outcomes, category membership has been commonly used to define individuals' baseline and end points. Examples include BMI category shifts from overweight to obesity (Brunner et al., 2007; Nyberg et al., 2012), absolute weight gain (i.e., Roos et al., 2013, examined those who gained >5 kg), and more relative percentage and percentile-based cut-points (e.g., Ishizaki et al., 2008, used >75th percentile weight gain as a threshold, and Niskanen et al., 2017, and Klingberg et al., 2019, included 10% and 20% gains of body weight to define 'major weight gain' category thresholds). As demonstrated above, when categories are broadly defined, such as WHO BMI categories, research that operationalises BMI and/or weight gain as a shift between categories may be limited in sensitivity (Preston et al., 2015).

Even the use of categories defined differently than standard WHO BMI categories is susceptible to overlooking the bulk of variation over time in BMI outcomes. Weight gain of the highest 10%–20% across participants is often considered in examinations of those who gain extreme amounts of weight (Zheng et al., 2017). Although dependent upon each sample analysed, in a large sample of 92,837 females and 25,303 males analysed by Zheng et al. (2017), the highest 10%–20% corresponded to an approximate gain of 20 kg or more, which is comparable with the example in Table 4.1 on shifting between BMI categories into the obese category. Thus, research adopting similar categorical thresholds is comparable to those focused on the larger and more extreme effects.

To reiterate, in mid-life annualised weight gain has been reported to be as little as .13 kg (Peeters et al., 2014). This provides further context to the importance of the length of follow-up

when examining weight gain during this life stage (e.g., the current chapter, which analyses individuals aged from 40–44 years old across 12 years until age 52–56 in the PATH Through Life study). Coupling the considerable width of the WHO BMI (or other broadly defined categories) with the average follow-up period of most longitudinal studies on job strain and BMI (i.e., the average in Table 4.2 is approximately seven years, although others have cited less than six years in more general bodies of research—e.g., Khoo et al., 2005), it appears that most of the studies on job strain and BMI over time that have used categorical thresholds were able to capture only the most extreme BMI variation over time, and that they were not designed to investigate modest changes.

4.2.3 The Importance of Modest BMI and Weight Gain

There is evidence that even a modest change in adiposity (and thus BMI) may be associated with increased health risks and, ultimately, mortality (Breeze et al., 2006). Zheng et al. (2017) analysed weight change in a longitudinal sample from early adulthood through to mid-adulthood (approximately 20–55 years of age). They examined change in weight with healthy ageing and, conversely, significant risk for chronic diseases across this 34-year age range. In the examination of both extreme (indicated by a gain of approximately 20 kg) and moderate (indicated by a gain of 2.5–9.9 kg) weight change, their findings demonstrated that greater amounts of weight gain were associated with increased risk for chronic diseases. While they found a dose-response trend for the strength of association with increased risk as weight gain increased, they also found that moderate amounts of weight gain were associated with significantly elevated risk for chronic disease, and, conversely, with decreased odds of achieving healthy ageing at age 55.

This represents evidence that modest weight gain, even amounts as small as 2.5–9.9 kg over the course of 34 years (for reference, when averaged annually, 9.9 kg across 34 years is a cumulative annual gain of .291 kg), can serve as a significant indicator for health risk. This is

consistent with a recent extension to the narrative surrounding health risk and adiposity that has traditionally been predominantly indicated by overweight and obesity. While obesity is an established risk factor for several chronic diseases and mortality (Prospective Studies Collaboration, 2009), there is a discussion of whether ‘healthy’ obesity exists (Wittert, 2018). This discussion is, in part, due to the presence of chronic disease in individuals within the ‘normal’ weight BMI category, and conversely, disease-free obese individuals. Indeed, a recent Australian ACT population health publication (Kelly et al., 2018) noted that the majority of overweight and obese individuals do not present with any metabolic disease indicators, and conversely, almost one-quarter of normal-weight individuals present with two such disease indicators. Consistent with this, it has been noted that if obesity is a disease in itself, it should be consistently measurably linked to health and wellbeing (Wittert, 2018). However, evidence supports that stable weight maintenance, rather than any loss or gain, may be an important factor for health (see Wittert, 2018, for a review).

Others have similarly discussed the importance of factors associated with BMI outcomes that are separable from the examination of BMI, or otherwise defined, category membership. For example, Zimmermann et al. (2013) supported the notion that weight maintenance is important in assessing health outcomes, and that change in weight over time is an important indicator for health. Further, Grundy (1998) discussed that even a smaller-than-average weight gain can lead to detrimental health outcomes in individuals with susceptibilities, or weight gain in combination with other risk factors such as reduced physical activity or low diet quality.

It is the view of the current thesis that the research investigating modest changes may be complementary to the established knowledge that obesity and BMI categories are indeed useful population health status indicators. The following sections review the literature on an association of job strain with BMI outcomes over time through the lens of the information provided above

regarding the benefits of examining modest changes in BMI without a focus on change across a threshold (i.e., continuous BMI).

4.3 Longitudinal Research on Job Strain and BMI Outcomes: A Literature Review

Tables 4.2 and 4.3 provide a synopsis of the longitudinal literature investigating job strain and BMI reviewed for the current thesis, presented by the categorical (see Table 4.2) or continuous (see Table 4.3) operationalisation of BMI. The studies have been restricted to those that use the JCQ (given the focus of this thesis on job strain) or a close variant. General working population research on job strain and BMI outcomes, including overweight and obesity, is limited, as reflected in the small number of studies identified and available for review in both Chapter 3 and the present chapter. This chapter's examination of this relationship over time restricts the available body of literature even further: Tables 4.2 and 4.3 show that this thesis identified that only 14 studies have examined a longitudinal association between job strain and BMI outcomes.

A quick overview of Tables 4.2 and 4.3 shows that the studies have sample sizes ranging from 633 to 56,262, with the sample size being somewhat dependent on whether the analyses were stratified by sex (four studies did not stratify analyses by sex—Azagba & Sharaf, 2012; Kivimäki et al., 2002, 2015; Nyberg et al., 2012—and two studies ran combined sex analyses in addition to stratified analyses—Brunner et al., 2007; Klingberg et al., 2019). Two of the four studies that pooled males and females showed a significant association between job strain (or elements of job strain) and higher BMI (Kivimäki et al., 2002; Nyberg et al., 2012); three of the 10 studies with male samples showed a significant association (Brunner et al., 2007; Klingberg et al., 2019; Niskanen et al., 2017) (although within these three, there was some attenuation based on adjustment for covariates, i.e., Brunner et al., 2007); and seven of the 11 studies with

female samples showed a significant association (although the significant results of these seven again varied depending on covariate adjustment, i.e., Brunner et al., 2007; Roos et al., 2013).

The inconsistent state of the findings in the cross-sectional literature is similarly reflected in the longitudinal research. The first step in understanding the inconsistent results is to highlight the heterogeneity in methods between studies (that may have contributed to the inconsistent results). This includes variation in the dependent variables measured (e.g., obesity, BMI change, body weight variation), variation in the culture and characteristics of working populations sampled, varying analytical models, and variation in the timeframe and the number of data points sampled across the follow-up period. Importantly, while only research modelled from the JCQ (Karasek et al., 1998), or close variants, to measure job strain, demands, and control, has been selected for review in this thesis (to narrow the focus sufficiently), the JCQ version varies among studies (e.g., Ishizaki et al., 2008, used the Japanese version; Brunner et al., 2007, employed an altered iso-strain version of the JCQ). Further, even where the same JCQ measure is employed, differences in the operationalisation of the JCQ for analysis are present in many studies (e.g., job strain scores operationalised categorically v. continuously in analysis/differing cut-points for the creation of categorical job strain, such as traditional median splits or tertiles; see Tables 4.2 and 4.3 for details).

Thus, while the reviewed studies often set out to measure the same or similar relationships/research questions at a general theoretical level, the results from varying methodologies need to be interpreted and contrasted cautiously. The following sections describe the past literature compiled in Tables 4.2 and 4.3 through the lenses of conceptual and analytical challenges present in the job strain and BMI literature. This description and discussion of the literature aims to highlight gaps and limitations to identify how an analysis of job strain and BMI outcomes over time using the PATH datasets can best contribute to future research.

Table 4.2

List of Studies Analysing Job Strain and BMI Over Time: Categorical BMI Outcomes (males shaded dark grey, females light grey)

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
Shields (1999) Canada	2,181 males	2 (2 years apart)	JCQ: used a ratio of demands to control; used highest quartile of this ratio to define categoric job strain	Categorical 'unhealthy weight gain' (defined as one std. dev. above average gain [6.4% for males, 8.8% for females], with average 'unhealthy weight gain' reported as 8.6 kg for males, 9.1 kg for females)	Multinomial logistic regression	Education, income, occupation, shift work, self-employment	NS (no other information available)
	1,649 females	As above	As above	As above	As above	As above	Positive association of job strain at baseline with unhealthy weight gain at follow-up (OR:1.8) (no other information available)
Brunner et al. (2007) England	3,413 females	4 (over 19 years)	Iso-strain-JCQ: cumulative count of job strain variable (derived via median split categorical job demands and control) and lowest tertile of social support combined	Categorical obesity at follow-up (BMI>30)	Multivariate logistic regression	Unadjusted	1 report of iso-strain (OR: 1.53, 95CI: 1.01–2.34) and 3 or more reports of iso-strain (OR: 3.38, 95CI: 1.16–9.80) significantly associated with increased obesity risk; 2 reports of iso-strain not significant (OR: .53, 95CI: .22–1.29)
						Age, employment grade, education, baseline health behaviours,	NS; 1 report iso-strain NS (OR: 1.18, 95CI: .70–2.01), 2 reports NS (OR: .74,

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
						follow-up health behaviours	95CI: .29–1.88), 3 or more reports NS (OR: 1.99, 95CI: .75–5.30); test of the linear trend was NS (p=.57)
						Unadjusted	2 reports (OR: 1.70, 95CI: 1.10–2.63) or 3 or more reports (OR: 1.92, 95CI: 1.13–3.24) of iso-strain significantly associated with increased obesity risk; 1 report NS (OR: 1.19, 95CI: .90–1.59)
						Age, employment grade, education, baseline health behaviours, follow-up health behaviours	NS; 1 report NS (OR: 1.15, 95CI: .90–1.47), 2 reports NS (OR: 1.52, 95CI: .97–2.40), 3 or more reports NS (OR: 1.64, 95CI: .95–2.84); test of the linear trend was sig. (p<.05)
						Age, employment grade, education, baseline health behaviours, follow-up health behaviours	3 or more reports (OR: 1.70, 95CI: 1.07–2.71) of iso-strain significantly associated with increased obesity risk; 1 report NS (OR: 1.16, 95CI: .89–1.50), 2 reports NS (OR: 1.22, 95CI: .81–1.83); test of the linear trend was sig. (p<.01)
Ishizaki et al. (2008) Japan	2,200 males	2 (6 years apart)	JCQ: Japanese variant including worksite support; categoric median split of job control, job demands; job	Categoric BMI (change from baseline—follow-up above 75th percentile v. those below)	Logistic regression analyses for categoric BMI change	Sedentary job type, shift work, smoking, alcohol, exercise, education, marital status	NS; males with high job strain at baseline and follow-up (OR: 1.23, 95CI: .95–1.59), reporting a change from baseline to follow-up (OR: 1.05,

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
			strain continuous (demands/control)				95CI: .82–1.35) when compared to those with low job strain at baseline and follow-up (reference)
	1,371 females	As above	As above	As above	As above	Sedentary job type, smoking, alcohol, exercise, education, marital status	NS; females with high job strain at baseline and follow-up (OR: .92, 95CI: .66–1.29), reporting a change from baseline to follow-up (OR: 1.05, 95CI: .77–1.44) when compared to those with low job strain at baseline and follow-up (reference)
Nyberg et al. (2012) Meta-analysis of 13 studies from UK/Europe	35,715 participants (controlled for sex)	2 (4 studies roughly 4 years apart)	JCQ: categorical using median split of job demands and control	Categorical obesity (BMI >30)	Fixed effects meta-analysis, pooled odds ratio	Sex, age, SES, smoking	Among those non-obese at baseline, job strain at follow-up was associated positively with incident obesity (OR: 1.18, 95CI: 1.02–1.36)
	6,507 participants (controlled for sex)	As above	As above	As above		As above	Individuals with job strain at baseline but not follow-up did not have a lower risk of incident obesity at follow-up (OR: 1.13, 95CI: .90–1.41)
Roos et al. (2013) Finland	~1,313 males	2 (5–7 years apart)	JCQ: median split job demands and control to create categories of job type, including job strain	Categoric outcome: major weight gain (defined as >5 kg)	Multinomial logistic regression	Age	NS; job strain predicting major weight gain NS (OR: 1.21, 95CI: .82–1.80)

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
						Age, baseline weight	NS; job strain predicting major weight gain NS (OR: 1.20, 95CI: .81–1.79)
						Age, baseline weight, alcohol consumption, physical exercise, smoking, common mental disorders, and limiting longstanding illness measured at baseline and employment status at follow-up	NS; job strain predicting major weight gain NS (OR: 1.07, 95CI: .70–1.63)
						Age	Job strain predicting major weight gain (OR: 1.25, 95CI: 1.05–1.49)
						Age, baseline weight	Job strain predicting major weight gain (OR: 1.23, 95CI: 1.03–1.47)
						Age, baseline weight, alcohol consumption, physical exercise, smoking, common mental disorders, and limiting longstanding illness measured at baseline and employment status at follow-up	Job strain predicting major weight gain NS (OR: 1.15, 95CI: .95–1.38)
Kivimäki et al. (2015) Meta-analysis of Roos et al. (2013),	Meta-analysis, N=18,240 combined sex	2 (4 studies, approx. 4.75 years apart)	JCQ: categorical job strain	Risk for weight gain (meta-analysis of four studies: 3 categorical weight	Fixed effects meta-analysis, pooled odds ratio (the authors note similar results with	Age, sex, SES	Job strain predicting weight gain NS (OR: 1.04, 95CI: .99–1.09)

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
Ishizaki et al. (2008), Shields (1999) and Kivimäki et al. (2006)				gain and 1 continuous BMI)	random effects modelling)		
Kivimäki et al. (2015) Meta-analyses by Nyberg et al. (2012); 13 studies from UK/Europe	Meta-analysis, N=42,222 (see Nyberg et al., 2012, above for further investigations)				Fixed effects meta-analysis, pooled odds ratio	As above	NS; job strain predicting obesity NS (OR: 1.00, 95CI: .89–1.13)
Niskanen et al. (2017) Finland Analysis of the same participants as Roos et al. (2013)	3,626 females	3 (phase 1: 2000/2002, phase 2: 2007, phase 3: 2012)	JCQ: categorical job strain; categorical median split of job demands and job control	Categorical major weight gain (defined as gain of >10% of baseline body weight at phases 1 and 3 (10/12 years later)	Logistic regression	Model 1: age at phase 1 Model 2: age at phase 1, marital status, occupational class, baseline BMI	High job strain at phase 2 (and no job strain at phase 1) associated with increased risk of major weight gain at phase 3 (OR: 1.31, 95CI: 1.07–1.61) High job strain at phase 1 and 2 not associated with increased risk of major weight gain at phase 3 (OR: 1.30, 95CI: 1.05–1.59) High job strain at phase 2 (and no job strain at phase 1) associated with increased risk of major weight gain at phase 3 (OR: 1.30, 95CI: 1.05–1.59) High job strain at phase 1 and 2 not associated with

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
	743 males						increased risk of major weight gain at phase 3 (OR: 1.20, 95CI: .92–1.55)
							High job strain at phase 1 (and no job strain at phase 2) not associated with increased risk of major weight gain at phase 3 (OR: 2.68, 95CI: .98–7.33)
							High job strain at phase 1 and 2 not associated with increased risk of major weight gain at phase 3 (OR: .65 95CI: .27–1.57)
						Model 2: age at phase 1, marital status, occupational class, baseline BMI	High job strain at phase 1 (and no job strain at phase 2) associated with increased risk of major weight gain at phase 3 (OR: 2.82, 95CI: 1.02–7.80) High job strain at phase 1 and 2 not associated with increased risk of major weight gain at phase 3 (OR: .59, 95CI: .24–1.44)
Klingberg et al. (2019) Sweden	1,798 males	3 (10 years apart, over 20 years)	JCQ—Swedish variant: categoric median split of job demands and decision latitude, used to create categoric job strain	Categorical major weight gain (defined as gain of >10% of baseline body weight at either 10- or 20-years follow-up)	Logistic regression	Model 1: age; model 2: age, baseline diet quality, social job support, physical activity, smoking, marital status, academic education, and BMI	Job strain not sig. associated with major weight gain over 10-years follow-up Model 1: NS (OR: .93, 95CI: 0.68–1.28); model 2: NS (OR: 1.09, 95CI: 0.71–1.67)

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
		20-year follow-up	As above	As above	As above		Job strain associated with increased risk of major weight gain- model 2: (OR: 1.38, 95CI: 1.01–1.88) Low decision latitude associated with major weight gain- model 2: (OR: 1.36, 95CI: 1.10–1.68)
	2,074 females	10-year follow-up	As above	As above	As above		Job strain associated with increased risk major weight gain- model 2: (OR: 1.38, 95CI: 1.12–1.69) High job demands associated with major weight gain, model 2: (OR: 1.28, 95CI: 1.05-1.56)
		20-year follow-up	As above	As above	As above		Job strain associated with increased risk of major weight gain, model 2: (OR:1.43, 95CI:1.08–1.89) High job demands at two time points (over 10 years) positively associated with risk for major weight gain, model 2: (OR: 1.28, CI95: 1.05–1.56)
	3,872 combined sex	10-year follow-up	As above	As above	As above	Model 1: age and sex; model 2: age, baseline diet quality, social job support, physical activity, smoking, marital status, academic education, and BMI	Job strain associated with major weight gain, model 1 (OR: 1.25, 95CI: 1.01–1.54); model 2: (OR: 1.28, 95CI: 1.03–1.60)

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result and context/comments
		20-year follow-up	As above	As above	As above		Job strain associated with major weight gain, model 1 (OR: 1.37, 95CI: 1.13–1.67); model 2 (OR: 1.38, 95CI: 1.12–1.69) Low decision latitude sig. associated with major weight gain, model 2 (OR: 1.26, 95CI: 1.03–1.53)

Notes. JCQ refers to the Job Content Questionnaire (Karasek et al., 1998) and close variants; NS = Not significant. Only main findings/inconsistencies within papers that are relevant are reported here for brevity; there are additional analyses reported in some papers that are not reported in this table.

Table 4.3*List of Studies Analysing Job Strain and BMI Over Time: Continuous BMI Outcomes*

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result
Kivimäki et al. (2002) Finland	812 participants (combined sex)	2 (10 years apart)	JCQ: tertiles of job strain and control	Continuous BMI	ANOVA	Baseline BMI, sex, age	High baseline job strain not associated with higher BMI at follow-up (P=.151) Lower baseline job control predicted significantly higher BMI (P=.008)
Kivimäki et al. (2006) England	2,418 females	2 (average 5-year follow up)	JCQ: modified (condensed), kept continuous in analysis	Continuous BMI	Multiple linear regression (B equals change in BMI per 1 s.d. increase in JDC score)	Baseline BMI, employment grade, age	Job strain NS (B .062, se .042, p=.14) Higher job demands associated with higher BMI at follow-up (B .099, se .046, P=.03) Job control NS (B -.013, se .048, =.79)
	5,547 males	As above	As above	As above	As above	As above	Job strain NS (B .0005, se .021, p=.82) Job demands NS (B .026, se .022, p=.23) Job control NS (B -.028, se .026, p=.28)
Ishizaki et al. (2008) Japan	2,200 males	2 (6 years apart)	JCQ: Japanese variant including worksite support; categoric median split of job control, job demands; job strain continuous (demands/control)	Continuous BMI at baseline and continuous BMI change from baseline to follow-up (ratio of change using BMI at baseline as denominator)	General linear models (GLMs) for continuous BMI; logistic regression analyses for categoric BMI change	Sedentary job type, shift work, smoking, alcohol, exercise, education, marital status	BMI at baseline: Males with high job demands at baseline and follow-up had higher baseline BMI (BMI=23.8, P=.04) than those reporting a change in job demands from baseline to follow-up (BMI=23.5) NS differences (p=.17) between the groups: low job control at baseline and follow-up (BMI=23.5), change in job control (BMI=23.6), high job

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result
							control at baseline and follow-up (BMI=23.8)
							BMI change from baseline to follow-up: NS difference ($p=.39$) in BMI change between males with high job demands at baseline and follow-up, and low job demands at baseline and follow-up, or if reporting a change from baseline to follow-up NS difference ($p=.36$) in BMI change between males with low job control at baseline and follow-up, change in job control, high job control at baseline and follow-up
	1,371 females	As above	As above	As above	As above	Sedentary job type, smoking, alcohol, exercise, education, marital status	BMI at baseline: NS differences ($p=.86$) between groups: low job control at baseline and follow-up (BMI=23.2), change in job control (BMI=23.1), high job control at baseline and follow-up (BMI=23.3); job demands NS ($p=.89$: BMI=23.1, 23.2, 23.2 for low demands at baseline and follow-up, a change, or high demands at both measurements BMI change from baseline to follow-up: NS difference ($p=.92$) in BMI change between females with high job demands at baseline and follow-up, or low job demands at baseline and follow-up, or if reporting a change from baseline to follow-up NS difference ($p=.56$) in BMI change between females with low job control at baseline and follow-up, change in

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result
							job control, high job control at baseline and follow-up
Eek & Östergren (2009) Sweden	5,488 females	2 (5 years apart)	JCQ: median split categoric job demands and control variables to create categoric job strain	Continuous BMI change	ANOVA	Education, marital status, country of birth, exercise, smoking	Middle-aged women (40–59 years) who reported baseline strain only ($\Delta\text{BMI}=.72$, $P=.04$) or longstanding strain (baseline and follow-up) ($\Delta\text{BMI}=.85$, $P=.019$) had significantly higher BMI than those who had never experienced strain ($\Delta\text{BMI}=.43$) and those who reported follow-up job strain only ($\Delta\text{BMI}=.57$)
	4,424 males	As above	As above	As above	As above	As above	No significant changes in BMI between middle-aged men (40–59 years) who reported baseline strain only ($\Delta\text{BMI}=.75$) or longstanding strain (baseline and follow-up) ($\Delta\text{BMI}=.74$), or those who had never experienced strain ($\Delta\text{BMI}=.49$) or follow-up job strain only ($\Delta\text{BMI}=.40$)
Block et al. (2009) US	722 females	2 (9 years apart)	Skill discretion, decision authority, job demands (job strain questionnaire, 1981)	Continuous BMI change	Multiple regression	Baseline BMI, health conditions, smoking, self-rated health, age-relative self-rated health, race/ethnicity, income, age, psychiatric diagnoses (depression, anxiety, panic)	Lack of skill discretion NS ($B=-.05$, $SE=.23$, $p=.84$) Lack of decision authority ($B=-.02$, $SE=.04$, $p=.64$) Job-related demands ($B=.38$, $SE=.26$, $p=.15$)
	633 males	As above	As above	As above	As above	As above	Lack of skill discretion NS ($B=.06$, $SE=.16$, $p=.72$) Lack of decision authority ($B=.03$, $SE=.15$, $p=.83$)

Author (year)	N	Data points (years)	Scale	BMI variable	Analysis	CVs	Result
							Job-related demands (B=.18, SE=.18, p=.30)
Azagba and Sharaf (2012) Canada	28,371 person year observations (combined sex)	4 (2 years apart, 2002–2008)	JCQ: tertiles of low, medium, high job strain (calculated as a ratio of control to demands)	Continuous BMI (self-report)	Fixed effects MLM: regression of independent variables onto BMI	Age, sex, marital status, education, income level, ethnicity, smoking, drinking, physical activity, time trend, workplace social support, health status, occupational fixed effects	High job strain NS (B=.006, SE=.046) Medium job strain NS (B=.025, SE=.042)
					Random effects MLM: regression of independent variables onto BMI	As above	High job strain NS (B=.032, SE=.036) Medium job strain NS (B=.013, SE=.033)
Fujishiro et al. (2015) US	56,262 females	2 (4 years apart)	JCQ: median split job demands and control to create categoric job strain	Continuous BMI change	Linear regression models	Age, race, parity	Positive significant association between longstanding job strain (follow-up and baseline) (Δ BMI = .125 [.052–.199], $P < .001$), and job strain at baseline only (Δ BMI=.073 [.017–.129], $P < .011$) or follow-up (Δ BMI=.077 [.013–.141], $P = .019$) and greater BMI change
						Age, race, parity, job type, average sleep, smoking, diet, physical activity, and average time watching TV	Positive significant association between longstanding job strain (follow-up and baseline) (Δ BMI=.118 [.044–.193], $P = .002$) and job strain at baseline only (Δ BMI=.063 [.006–.120], $P = .030$) or follow-up only (Δ BMI=.074 [.009–.138], $P = .025$) and greater BMI change

Notes. JCQ refers to the Job Content Questionnaire (Karasek et al., 1998) and close variants; NS = Not significant. Only main findings/inconsistencies within papers that are relevant are reported here for brevity; there are additional analyses reported in some papers that are not reported in this table.

4.3.1 Studies That Examined Categorical BMI Outcomes

Table 4.2 identified eight studies that used the JCQ (or a close variant) to examine associations with categorical BMI outcomes over time. For example, Nyberg et al. (2012), Brunner et al. (2007), and Kivimäki et al. (2015), using a BMI threshold of 30, reported on associations of job strain with crossing the threshold into obesity over time. Other studies similarly used categorical outcomes, albeit defined differently, such as ‘major weight gain’ (Klingberg et al., 2019; Niskanen et al., 2017; Roos et al., 2013), ‘unhealthy weight gain’ (Shields, 1999), and ‘BMI change above the 75th percentile’ (Ishizaki et al., 2008). These latter categories used thresholds that were relative to individuals’ baseline weight/BMI rather than the objectively defined WHO categories of overweight and obesity.

There are inconsistent findings among longitudinal studies investigating job strain and categorical BMI outcomes over time, including among studies that used thresholds capturing greater BMI change over time. Brunner et al. (2007), Nyberg et al. (2012), and Kivimäki et al. (2015) analysed the transition into the obesity category at follow-up. Brunner et al. (2007) reported support for an association of job strain with entrance into obesity. Nyberg et al. (2012) reported evidence for the co-occurrence of obesity and job strain at follow-up, but no evidence for a prospective association, leaving doubts over any causal relationship. However, the same longitudinal data examined in Nyberg et al. (2012) were reported in a review by Kivimäki et al. (2015), who simultaneously reported a new meta-analysis with different data, finding no further evidence for an association. Ishizaki et al. (2008) used a threshold that was similarly representative of a larger change in BMI over time (BMI increase across the longitudinal study above the 75th percentile) and also did not find any support for an association of job strain with BMI outcomes. Thus, while there is some support for an association of job strain with BMI outcomes among studies analysing broader categorical BMI outcomes, the findings are inconsistent.

To date, just two studies have used categorical thresholds that were more in line with what would be considered moderate weight gain (rather than larger/major weight gain). Roos et al. (2013) and Shields (1999) found some evidence suggesting that job strain was associated with moderate weight gain. Specifically, Shields et al. found some support for job strain to predict ‘unhealthy weight gain’ in females (indicated as one standard deviation above average weight gain, corresponding to an average gain of 8.8% [9 kg] of baseline weight in their study). Even more moderate, Roos et al. defined their ‘weight gain’ category as a gain of 5 kg or more and found that job strain significantly predicted increased odds of gaining at least 5 kg for females. These findings were consistent with those of Shields et al. until further adjusted for lifestyle variables (thought to mediate the relationship), although Roos et al. specifically noted the positive direction of the association despite this. In comparison, Shields et al. did not control for lifestyle variables, making it difficult to compare beyond this point.

There are too few studies with categorical outcomes to conclude whether there are reliable differences between studies with larger versus more moderate BMI thresholds over time. Despite this, it is possible that, given the small anticipated size of an association, increasing the cell sizes in analyses by lowering the threshold for category inclusion and examining more modest variations in BMI may have enabled the effect of job strain to be detected in the analyses of Shields et al. and Roos et al. Beyond this, studies analysing categorical BMI outcomes together indicate mixed support for a relationship between job strain and BMI outcomes over time. It is likely that other contextual factors may also be important, such as follow-up length, the power and sample size of the study, change over time, and sex differences, which are addressed further below.

4.3.2 Studies That Examined Continuous BMI

Seven studies listed in Table 4.3 have examined an association between job strain or its components (job demands and control) and continuous BMI outcomes over time. A general overview of these studies shows that clear and consistent findings are not readily available. Five of the seven studies reported *some* support for an association (Eek & Östergren, 2009; Fujishiro et al., 2015; Ishizaki et al., 2008; Kivimäki et al., 2006; Kivimäki & Paivi, 2002). Kivimäki et al. (2002) reported finding a negative association between reported low job control at baseline and higher average BMI after 10 years in a working sample. In a different working sample, Kivimäki et al. (2006) reported on a longitudinal association between job strain, its components, and BMI. They did not find evidence for a main effect of job strain or job demands in association with BMI for males or females, but they found a weak association between higher job demands and increased BMI after five years in females. In a sample of Japanese workers, Ishizaki et al. (2008) found that those who experienced high job demands at baseline and follow-up had higher BMI at the start of the study (compared with those who reported low job demands or a change in job demands over the study), although this finding was not supported in various other analyses by Ishizaki et al. (2008).

A later study by Eek and Östergren (2009) shared many similar characteristics with that of Kivimäki et al. (2006). Both studies had sample sizes in the thousands, both had a five-year follow-up period over which BMI information was collected at two data points, and both assessed increasing BMI as the outcome. However, despite the many similarities, the authors each operationalised the analysis of the job strain measure differently. Eek and Östergren reported on differences in BMI from baseline to follow-up by job strain category, and Kivimäki et al. reported on associations of increasing BMI with continuous job demands and control scores.

The differing operationalisations complicate the comparison of the study outcomes. Eek and Östergren found a weak positive relationship between females who either reported job strain at baseline, or at baseline and follow-up, with higher BMI at follow-up, compared with women who had never reported job strain. Kivimäki et al. found, more specifically, that job demands at baseline (the JCQ scales were only measured at baseline) significantly predicted increased BMI at follow-up in females. Fujishiro et al. (2015) analysed a large sample of 56,262 females and found further support for an association of job strain with BMI over time. They reported a positive association between job strain and BMI increase over time, but similar to Eek and Östergren, they did not report on associations between the component subscales of job strain (job demands and control) with BMI outcomes. It is not known whether further analysis of these subscales by Eek and Östergren, and Fujishiro et al., would also reveal whether the job demands scale was the influential factor in the significant relationship reported between job strain and increased BMI at follow-up. Despite this, each study lends support to evidence for an association of job strain (or its components) with BMI outcomes over time for females.

While each of these studies briefly reported some significant evidence, other studies have not found support for a relationship between job strain and continuous BMI over time. For example, Block et al. (2009) and Azagba and Sharaf (2012) did not find evidence for the main effects of job strain or its component subscales on male or female BMI over time. Although the null findings of these two studies agree, the methods and analyses used in each study differed substantially. Block et al. (2009) analysed BMI change over approximately eight years in association with a lack of skill discretion and decision authority, and job-related demands. They entered the psychosocial job quality variables as continuous scores into analyses predicting BMI change, finding no main effects. In contrast, Azagba and Sharaf measured job strain and BMI at four time points over six years. They calculated the ratio of

psychological job demands and decision latitude to indicate job strain, which was categorised into high, medium and low job strain tertiles. They analysed these scores in association with BMI using random and fixed effects MLMs, finding no evidence for an association. Thus, while some studies have provided evidence of an association between job strain and continuous BMI over time, there are also null findings, reiterating the inconsistent state of the literature and the need for further contributions to the research body.

4.3.3 Summary of Studies Analysing Categorical and Continuous BMI

The separation of the literature based on categorical and continuous BMI outcomes does not, by itself, clarify the state of evidence reported in the results. This is because some evidence for an association of job strain with BMI over time is present among both studies that analysed categorical and continuous BMI outcomes. Overall, while some studies report statistically significant evidence for an association, this evidence is weak and variable, and evaluating the evidence for a relationship requires more than the examination of significant results. To complement this, a deeper review of other contextual factors is required, such as longitudinal analysis methods employed, change versus changes over time, length of follow-up, and consideration of the differing strength of evidence between male and female samples. While the heterogeneity among studies makes it difficult for this thesis to contrast the findings and inconsistencies in a clear manner, the following sections explore these themes within the evidence that highlight potential gaps in the literature for future research.

4.3.4 Longitudinal Analysis Methods and the Examination of Change Over Time: The Utility of Multi-Level Models in Research on Job Strain and BMI

It has been discussed that the determinants of BMI are complex and multifactorial, with the effect of most likely small, coalescing together to produce the observed BMI at a particular time point and influence change in BMI over time. In combination with the generally slow rate of increasing BMI over time, investigations require sensitivity to these

considerations. However, doubts have been expressed regarding the power of investigations that have examined the association between job strain and BMI outcomes (Kivimäki et al., 2015). This concern is made more serious by the anticipated small size of the relationship between job strain and BMI over time, if present (Berset et al., 2011; Kivimäki et al., 2015; Nyberg et al., 2012; Wardle et al., 2011). Because the loss of information that can occur with the categorisation of underlying continuous variables can reduce the power of analyses (Altman & Royston, 2006; Bennette & Vickers, 2012) the examination of BMI continuously is one method of increasing the power and sensitivity of investigations to detect an association (Bennette & Vickers, 2012; Cohen, 1983; Hansen & Collins, 1994). Additionally, the utility of more sensitive longitudinal methods for increasing the power and sensitivity of analyses to detect a relationship (Singer & Willett, 2003) lays the basis for the analyses conducted in the current chapter.

Appropriate longitudinal research methods, particularly in prospective longitudinal studies, can provide more robust estimates than cross-sectional analytical methods because they are less susceptible to errors produced by unobserved individual-level variation (Azagba & Sharaf, 2012; Lu et al., 2013). Individual-level variation can be estimated by sampling the same individuals over time. MLMs are more complex general linear models and are suitable for this purpose because they can account for hierarchical structures in the data they are used to analyse. When applied to longitudinal data, they can examine and separate the effects of time and between-person and individual-level variance, which can then be separated from estimates related to the measured variables of interest (Field, 2000; Singer & Willett, 2003; Kwok et al., 2008).

These methods are particularly suitable when the outcome variable is determined by individual-specific characteristics (Singer & Willett, 2003) such as BMI. It is evident that an upward shift in BMI is occurring on average over time. Despite this, the aetiology of BMI

increase, and outcomes such as obesity and overweight, are complex and vary widely from individual to individual (Cornier et al., 2011; Selassie & Sinha, 2011). The ability to account for this individual-level variance is important (Livshits et al., 2012), and being able to account for more individual-level variance can reduce error variance (Leyland & Groenewegen, 2020; Weinmayr et al., 2017). In turn, the estimates produced are often regarded as more accurate and robust against statistical confounds and error. Given the greater power and more robust nature, prospective longitudinal methods are suitable for the investigation of smaller effects such as those hypothesised between job strain and BMI outcomes.

However, most of the studies that have examined associations of job strain with BMI over time have been limited in their analysis methods. Each study that categorised BMI used logistic regression models (Brunner et al., 2007; Ishizaki et al., 2008; Klingberg et al., 2019; Niskanen et al., 2017; Nyberg et al., 2012; Roos et al., 2013; Shields et al., 1999). Further, of the studies that analysed BMI continuously, two used ANOVA (Eek et al., 2009; Kivimäki et al., 2002) and four used linear regression techniques (Block et al., 2009; Fujishiro et al., 2015; Ishizaki et al., 2008; Kivimäki et al., 2006) as the primary methods for analysis. These investigations did not account for individual-level variance. The possibility remains that the mixed findings may be, at least in part, a result of unobserved factors that cannot be controlled for using such modelling techniques (Azagba & Sharaf, 2012).

Azagba and Sharaf (2012) recognised that the investigation of job strain and BMI outcomes may benefit from the use of more powerful and sensitive methods that are able to account for unobserved individual-level variation. Using a Canadian population-based dataset (data from waves four to eight), the authors employed MLM analytic techniques to assess whether job strain was associated with BMI over time. They reported on two related, but different, MLM models: a fixed effects (within-subjects) and a random effects (within-

and between-subjects) model. Neither model found evidence that BMI differed over time among individuals experiencing high, intermediate, or low job strain (operationalised as tertiles in analysis). The unbalanced panel sample analysed included 28,371 person-year observations. The large sample size used in their analyses provides extra confidence in the results.

Of interest, Azagba and Sharaf (2012) employed ordinary least squares regression as a first step to estimate the association of job strain with BMI on the same dataset when the data from the four waves were pooled cross-sectionally. Their analyses returned evidence of a significant positive association in contrast to the null results from their longitudinal MLM analyses. Of further note, Shields (1999) analysed data on weight change in association with job strain from the same individuals at earlier waves (waves one to two) of the same population study using logistic regression to model categorical weight change. Shields reported a positive significant association between the likelihood of weight gain among females who experienced job strain. These contrasting findings within the same dataset further support that some of the inconsistency within the literature may be, at least in part, a result of the analysis technique selected and the ability/inability of the analyses to control for unobserved individual-level variation. While their longitudinal results suggest there was no evidence for consideration, Azagba and Sharaf (2012) concluded that there is a need for further high-quality longitudinal evidence to better understand the relationship between job strain and BMI.

However, to date, it appears that only one other study has used MLM analysis techniques. Kivimäki et al. (2015) similarly employed both fixed and random effects MLMs in a meta-analysis of four cohort studies and found no support for the notion that job strain is an important determinant of, or associated with, BMI over time. Their meta-analysis included a selection of the cohort studies by Shields et al. (1999), Kivimäki et al. (2006), Ishizaki et al.

(2008), and Roos et al. (2013), reviewed above. Three of the four studies included in the meta-analysis reported positive significant findings for a relationship between job strain and BMI outcomes over time. Despite this, both the fixed and random effects meta-analyses reported no evidence for an association over time, similar to the results of Azagba and Sharaf (2012).

Further to the fixed and random effects MLM analyses, Kivimäki et al. (2015) reported the results of their earlier longitudinal meta-analysis (using a fixed effects meta-analysis originally reported in Nyberg et al., 2012). While this meta-analysis did not find evidence for a prospective association of job strain with BMI outcomes at follow-up, evidence was reported for the co-occurrence of both job strain and incident obesity at follow-up (Kivimäki et al., 2015; Nyberg et al., 2012). Thus, a deeper review of the studies and results within Kivimäki et al. shows some discrepant evidence, similar to the discrepant results reported by Azagba and Sharaf (2012) and in contrast with Shields' (1999) analysis of the same participants at earlier waves.

The two existing MLM analyses that examined the association of job strain with BMI over time found no evidence to support such a relationship, in contrast to other longitudinal analytic techniques in other studies (e.g., Fujishiro et al., 2015). In consideration of the multifactorial nature of BMI and the more powerful and sensitive nature of the MLM analyses, the MLM analyses appear to be the more suitable analytic choice for the study of job strain and BMI over time. While MLM techniques are regarded as being able to produce estimates that are more accurate and robust, lending credibility to the null findings reported, there are still other factors to be considered when appraising the overall state of the literature for evidence of an association of job strain and BMI over time. Such factors include the separate analysis of data by sex (which may have confounded the results of the MLM

analyses reviewed here), the analysis of change versus *changes* over time, and the length of follow-up examined. These factors are explored and discussed below.

4.3.5 Sex Differences

As discussed in earlier chapters (i.e., section 1.7), empirical studies on general stress show associations with BMI outcomes that are thought to occur through both direct (biological) and indirect (behavioural) mechanisms (Chandola et al., 2008; Marmot et al., 2006; Siegrist & Rödel, 2006). However, there is evidence that females and males may respond differently to stress, which affects BMI outcomes differently (Matud, 2004; Mikolajczyk et al., 2009; Papier et al., 2015). Consideration of the literature reviewed in Table 4.2 shows greater evidence for an association of job strain, or its components, with BMI outcomes over time for females than for males.

Eleven studies in Tables 4.2 and 4.3 analysed associations in females separately from males, with seven of those studies reporting some evidence for a positive association of low job control, high job demands, and/or job strain with BMI over time. For males analysed separately, just three out of 10 studies reported some evidence. However, adjustments for likely mediating factors change this to five out of 11 studies for females and two out of 10 studies for males. Although the limited research base available for review must be considered in the discussion in this chapter, the available evidence suggests that an association of job strain with BMI outcomes over time may be more evident among females. This aligns with the systematic review of work stress and obesity, including BMI outcomes, conducted by Solovieva et al. (2013), who suggested the presence of stronger evidence for an association in females rather than in males. In addition to evidence for sex-differentiated stress response patterns, explanations for the suggested differences between sexes include that males and females may be employed in varying occupations and positions and thus experience different working conditions (Solovieva et al., 2013).

A closer review of the MLM studies conducted by Kivimäki et al. (2015) and Azagba and Sharaf (2012) also highlights the potential for sex differences to be an important consideration. However, the possibility that an association of job strain with BMI over time may differ by sex was not explored in either study, because each combined sexes in the analysis. While Kivimäki et al. (2015) briefly reviewed the studies included in their systematic review by sex, neither Azagba and Sharaf nor Kivimäki et al. reported testing their analyses separately by sex, testing an interaction with sex, or discussing the possible implications of this. However, three of the four studies pooled in the meta-analysis conducted by Kivimäki et al. reported differential results by sex: Roos et al. (2013), Kivimäki et al. (2006), and Shields et al. (1999) reported finding some evidence for a significant association of job strain (or its components) with females, but not with males. While combining sex in analyses is a common method of boosting power by increasing observations, this may have diluted the strength of the association with either sex, biasing the results towards the null in the pooled analyses.

4.3.6 Data Points and Measurement of Change in Longitudinal Studies

Most of the longitudinal literature on job strain and BMI over time has only had the ability to analyse one measurement of change in BMI (i.e., one difference score). This is different from analysing *changes* over time among job strain and BMI. Longitudinal research differs from cross-sectional research because a temporal element is considered; namely, data are considered over a length of time. The minimum number of data points required to examine an association longitudinally over time is two; however, the analysis of only two data points is a limited examination that may or may not include an analysis of one measurement of change (e.g., if the predictor variable is measured prior to the dependent variable, a longitudinal association is measured without a measurement of change; *change* is measured through the same variable measured at two different time points).

Further, it is argued that the analysis of one measurement of change only is not an analysis of change *over time* because only one difference score is analysed (Singer & Willett, 2003). The analysis of change *over time* requires a minimum of three data points to be observed, thus collecting information on a minimum of two measurements of change. One measurement of change over time does not provide information on what a pattern of *changes* over time may look like—for example, whether changes are consistent, or vary, at different points across time. Further, one difference score (one measurement of change) does not allow for the accurate estimation of error, posing a confound (Singer & Willett, 2003). Thus, while an examination of two data points across time is the minimum for longitudinal research, change over time requires three data points measuring the dependent variable over time, which enables the analysis of *changes* over time.

Within the small body of longitudinal literature on job strain and BMI outcomes, it is rare that any study has had the ability to analyse more than two data points. Ten of the 14 studies reviewed in Tables 4.2 and 4.3 had data at only two time points. While these 10 studies reported an examination of change in BMI over time (BMI was measured at both baseline and follow-up), only one measurement of change was observed. Thus, no actual *changes* over time were analysed in these studies. Only four studies have had three or more measures of job strain and BMI: Niskanen et al. (2017) and Klingberg et al. (2019) reported on data collected at three time points, while Brunner et al. (2007) and Azagba and Sharaf (2012) reported on data collected at four time points. Niskanen et al. (2017), Klingberg et al. (2019), and Brunner et al. (2007) reported finding some evidence of an association between job strain and increased BMI outcomes, including incident obesity (Brunner et al., 2007). However, each study used logistic regression methods (which have less ability to account for missing data) and were limited in their ability to model within-person change in job strain and BMI over time together. Thus, Azagba and Sharaf's (2012) study was the only one to

have four data points and to use more advanced longitudinal methods to examine changes in job strain with changes in BMI over time (in a fixed effects analysis). While the findings of their longitudinal analyses found no evidence for an association of job strain with BMI over time, the authors encouraged further longitudinal research to support their findings. Certainly, with so few studies reporting on the co-occurrence of job strain and BMI over time, and only one of these analysing *changes* over time, further research is needed to explore within-person changes more robustly over time.

4.3.7 Length of Follow-Up

A further point for consideration is the length of the follow-up in each longitudinal study and how it may affect the results. It has been discussed above and evidenced that weight, and thus BMI, typically changes relatively slowly over time, with some reporting an increase of half a kilogram per year on average, and others reporting less, particularly in mid-life (Mozaffarian et al., 2011; Peeters et al., 2014; Shields, 1999; Zheng et al., 2017). A longer follow-up time may better suit the slower rate of change observed in BMI, thereby increasing the power to detect a relationship through a better fit between the investigative methods and the nature of the variables under consideration. Supporting this, a meta-analysis of work stress with BMI outcomes noted that studies with longer follow-up times were more likely to detect a significant association (Wardle et al., 2011).

Of the studies included in Tables 4.2 and 4.3, only four reported on a follow-up of between 10 and 20 years, and the average length of follow-up was approximately 5.3 years for the other 10 studies. The studies with the longest follow-ups found some significant associations of job strain, or its components (job demands and control) with BMI outcomes. Niskanen et al. (2017) found that an increase in job strain over time was associated with increased risk for major weight gain at the 10-year follow-up for females, and a decrease in males' job strain was associated with increased risk for major weight gain. Over the longest

follow-up periods to date (two studies across approximately 19–20 years), Brunner et al. (2007) found evidence for an association of job strain with incident obesity, and Klingberg et al. (2019) reported that high job demands and high job strain were associated with major weight gain. Specifically, Klingberg et al. (2019) found evidence that job strain was associated with increased risk for major weight gain at both the 10- and 20-year follow-ups in combined sex analyses and for females. However, while job strain was associated with higher risk of major weight gain at the 20-year follow-up for males, this was not the case at the 10-year follow-up. Additionally, Kivimäki et al. (2002) and Klingberg et al. (2019) found evidence for an association of low job control with increased BMI outcomes at the 10-year follow-up.

Klingberg et al. (2019) has been the only study to date to report on the association within the same sample at two different follow-up lengths: 10 and 20 years. The results reported unique information about the possible dynamic nature of an association of job strain or its components with BMI outcomes over time. In combined sex analyses, the association of job strain with major weight gain increased marginally at the 20-year follow-up compared to the 10-year follow-up. However, when analysed separately by sex, despite no evidence that job strain was associated with major weight gain at the 10-year follow-up for males, there was evidence for a significant association at the 20-year follow-up. For females, the association was significant at both follow-up lengths, although the estimate of association was reported to decline marginally at the longer follow-up.

In further analyses of the components of job strain, job demands was associated with major weight gain at the 20-year follow-up, but not at the 10-year follow-up. Further, Klingberg et al. (2019) reported that, while the association of low job control with major weight gain was significant at each follow-up length, the strength of the association increased modestly at the 20-year follow-up. This suggests that the length of time may influence the

association. While some of these results may reflect the cumulative nature of weight gain over time, which allows an association of high job strain on BMI to develop across longer periods, it is a complex pattern of results that is difficult to explain.

However, that the length of follow-up may be an important consideration contrasts with the results reported by Kivimäki et al. (2015). In their fixed (and supplementary) random effects meta-analyses of four studies, they noted that their null result did not depend on the differing lengths of follow-up among the studies. However, the average length of follow-up for the studies included in their meta-analysis was just 4.75 years. This raises a point that is applicable not just to their meta-analyses, but also to the majority of studies reviewed in this chapter—that is, that longer follow-up lengths may increase the chance of detecting an association if one is present. However, given that studies with short follow-up periods occasionally find an association (which may occur because of a range of factors, e.g., sample differences, issues of power and type one errors), the inconsistency in findings makes it difficult to confidently conclude that this is the case.

4.4 Aims

This chapter has reviewed the longitudinal research investigating job strain in association with BMI over time. The inconsistency in the findings of existing studies and the methodological limitations identified lead to the main research question proposed in this chapter: Is job strain associated with BMI outcomes over time? The multiple ways in which existing longitudinal research have investigated the relationship between job strain and BMI over time (and the varying results) suggest there is value in further exploring this relationship using a variety of models within the same prospective dataset. Analysing the data using multiple models with the same sample allows the assessment of whether discrepancies amongst prior results were due to methodological and sample differences. By using the same dataset, differences in sample and measurement are controlled for, and the results of

alternative analyses and models can be more easily compared. With data on job strain and BMI assessed at four time points over a 12-year follow-up, the PATH Through Life dataset is richly placed for this examination.

The analyses in this chapter take an explorative approach using the multiple time points available in several different sets of models to investigate potential differences surrounding job strain and BMI outcomes over time. An aim of the current chapter is to extend the analyses of previous studies with the use of MLM techniques, employing both random and fixed effects models to align the analytic methods with the dynamic, multifaceted, and slow-developing nature of BMI over time. For example, baseline job strain MLM analyses are conducted to maximise the long follow-up time available to investigate whether BMI over the 12-year follow-up period is associated with an experience of job strain at the beginning of the study. Further, a lagged set of MLM analyses examines an association of job strain at a prior wave with BMI at a subsequent wave. This enables three lags to be averaged over the four data points—each lag over a four-year period—and provides insights into any differences via the length of follow-up. Further, given the evidence that suggests a more robust association among females, the current analyses are conducted separately by sex. Following the literature review, this particular combination of analytic choices aims to maximise the features of the PATH dataset to contribute meaningfully to issues identified in the existing body of literature on job strain and BMI over time. This is the first longitudinal investigation of an association among job strain and BMI over time in an Australian sample, and it aims to expand the Australian body of research in this area that, to date, has only been cross-sectional.

While the sets of models all vary somewhat in the specific research question they address, they all connect to the proposition that job strain is in some way related to BMI

outcomes over time. The specific research questions (aligned with the four analyses/models) are as follows:

1. When multiple observations are available over time (increasing the power to detect significant effects), is job strain associated with BMI levels (general random effects model)?
2. Are changes in job strain associated with changes in BMI levels over time (when unobserved variance between individuals is reduced) (fixed effects model)?
3. Does job strain at baseline affect BMI levels over the subsequent 12 years (baseline job strain model)?
4. Does job strain at one time point predict BMI levels at the subsequent time point four years later (lagged job strain model)?

All of the research questions and models use multiple observations from each respondent, which goes some way to overcoming the lack of statistical power that is often problematic in cross-sectional and small-sample studies. In addition, the outcome variable adopted is continuous BMI, which provides greater sensitivity to BMI variation compared to using BMI categories. Similar to the studies by Azagba and Sharaf (2012) and Kivimäki et al. (2015), the analyses use sensitive longitudinal modelling techniques—fixed and random effects MLMs, to answer the focal research questions. The first two research questions (1 and 2) seek to maximise the multiple observations that are available to robustly examine whether there is a direct association between job strain and BMI levels over time. However, dissimilar from both Azagba and Sharaf (2012) and Kivimäki et al. (2015), the current analyses are conducted separately for males and females given the discussion of past research that indicates an association may differ by sex. Further, while Azagba and Sharaf are the only authors to use sensitive analytic modelling techniques to analyse four data points across an approximate eight-year period, the current study analyses the association over a longer

follow-up period of approximately 12 years. Thus, the second two research questions (3 and 4) capitalise on this and introduce an element of temporality to test whether job strain at an earlier time point has an association with BMI levels at subsequent time points. This reflects the majority of the prior literature, which has collected job strain information at the beginning of the study only.

4.5 Methods

4.5.1 Participants

This chapter used data collected from participants in the 40s cohort enrolled in the PATH Through Life survey, which sampled participants from the Canberra and Queanbeyan regions of Australia (ACT and NSW, respectively). It analysed four waves of data collected approximately every four years beginning in 2000, with data collection for wave four of the 40s cohort beginning in 2012. Detailed information on participation rates per wave for the 40s cohort is available in the methods chapter (see Chapter 2). For the current analyses, the inclusion criteria were that participants were in the 40s age cohort, employed either full or part time, and had information on the JDC scales (at each wave). This left 1,130 males and 1,141 females who met these criteria at wave one, 1,030 males and 1,076 females at wave two, 976 males and 1,021 females at wave three, and 700 males and 745 females at wave four. However, not all participants had information on all relevant covariates and BMI; given this, the multivariate samples differed slightly between MLM analyses (although within each type of MLM analyses, to ensure the models were comparable with and without covariates, the same sample was used in both the restricted/simple [model A] and multivariate/adjusted models [model B]).

4.5.2 Measures

The key measures used throughout all analysis chapters in this thesis were described in detail in the methods chapter (see Chapter 2). However, a brief overview of the

independent, dependent, and covariate variables, and any specific information that pertains to this chapter, is provided below.

4.5.2.1 Job Strain

At each wave, a variant of the JCQ (Karasek et al., 1998) was used to measure job demands (four items), skill discretion (six items), and decision authority (nine items), which were combined to measure job strain. Participants responded to each item using a four-point Likert scale, and items were summed for each scale to create a score for job demands and job control (job control included both skill discretion and decision authority items). Scores on the job demands and control scales were then split at the median to create dichotomised high and low job control and high and low job demands categories, where 0 represented high (scores above median scores) and 1 represented low (scores below median scores). The median values used were wave-specific and were largely comparable across waves. High job strain (coded as 1) was categorised when participants' scores demonstrated low job control and high job demands, and a no strain category (coded as 0) was indicated in the absence of this combination.

4.5.2.2 BMI

BMI was calculated using participants' weight in kilograms divided by their height in metres squared (weight [kg]/height [m²]). Participants self-reported their weight at every wave to the nearest kilogram. Their height was self-reported only at waves one and two. Wave one height was used to calculate participants' BMI because it had a higher response rate than wave two; however, where wave one data were missing, wave two data were used instead, if present. Participants' observations of BMI less than 18.5, classified as underweight by WHO standards, were excluded from the analyses (25 participants at wave one, 16 at wave two, 12 at wave three, and 11 at wave four). However, these participants were not permanently dropped from the dataset because their BMI was able to increase above 18.5

variably across waves. In line with similar studies (e.g., Nyberg et al., 2012; Ostry et al., 2006; Paige et al., 2014), six female (three observations at wave one, two at wave two, and one at wave three) and 12 male (six observations at wave one, three at wave two, and three at wave three) participants' observations of BMI greater than 50 were also removed from the analyses variably across waves because prior literature shows greater measurement error in the extremes of BMI, especially with self-report methods (Preston et al., 2015).

4.5.2.3 Covariates in Fully Adjusted Analyses

For consistency, the covariates included were the same as those used in the prior chapter, though four waves of data on each covariate was available within the longitudinal analyses. The covariates are described in detail below and estimates are reported in the results, however, the estimates reported are not total-effects estimates similar to job strain, the main variable under investigation, and thus cannot be interpreted as such (Westreich & Greenland, 2013; see Chapter 2 for a further explanation of the covariate estimates reported).

4.5.2.3.1 Smoking

At each wave, participants indicated whether they were a current smoker, which was categorically coded as 1 'Yes, currently smoking' and 0 'Not currently smoking' and was included in all fully adjusted analyses.

4.5.2.3.2 Children

Whether participants had children or not at each wave was coded into one of two groups following their 'Yes' or 'No' response to the question 'Do you have any children?' (0 = 'No children' and 1 = 'Yes, children'). A positive 'Yes' response was inclusive of children who were adopted, stepchildren, and children not currently living with the participant.

4.5.2.3.3 Financial Hardship

A binary financial hardship indicator was created for each wave where 0 represented no financial hardship and 1 represented financial hardship. A positive response to any of four

questions assessing financial hardship led to categorisation of that participant as experiencing financial hardship.

4.5.2.3.4 Physical and Mental Health

Self-rated physical and mental health were controlled for in all fully adjusted analyses using the PHC and the MHC of the SF-12, which was scored using the RAND-12 method. Participants' scores for each scale were then entered continuously into each analysis.

4.5.2.3.5 Education

Years of education, measured at wave two of data collection, were entered continuously into all fully adjusted analyses. As this was a time invariant variable, education was omitted from all fixed-effects analyses.

4.5.2.3.6 Work Hours

All fully adjusted analyses included a continuous measure of the number of hours that participants worked in a routine week, including unpaid overtime and work taken home, which was recorded at each wave.

4.5.2.3.7 Exercise

At each wave, participants were assigned to one of three categories depending on the intensity and number of hours of exercise they reported per week, corresponding to high, moderate, or low amounts of exercise and its intensity. This was based on the Whitehall study exercise categories (Department of Epidemiology & Public Health, 1991), in which those reporting more than 1.5 hours of vigorous exercise per week were coded as group 2, indicating high amounts and/or intensity of exercise, those reporting more than 1.5 hours per week of moderate exercise, but less than 1.5 hours per week of vigorous exercise, were coded as group 1, indicating moderate amounts and/or intensity of exercise, and those reporting less than 1.5 hours of moderate exercise were coded as group 0, indicating low intensity and amount of exercise.

4.5.3 Statistical Models and Analyses

Initially, a null MLM of BMI across time was modelled to measure how much variation in BMI occurred at the intercept (between participants at the beginning of the study) and across time (intra-individual variation in BMI across the four waves of data). Subsequently, four sets of MLMs were conducted using all four waves of available data to investigate an association of job strain with BMI over time:

1. General random effects models: The first model examined job strain in association with BMI levels using a random intercept model (the random intercept allowed participants to vary in their baseline BMI scores).
2. Fixed effects models: The second model examined changes in job strain in association with changes in BMI over time using a fixed-effects model. The analysis excluded any time-invariant variables.
3. Baseline job strain models: The third model included only the baseline job strain score (also using a random effects model that allowed participants' baseline BMI to vary) to examine associations with BMI scores over the four-year intervals between data collection points.
4. Lagged job strain models: The fourth model included a lagged variable for job strain to assess whether job strain at a prior time point predicted subsequent BMI at the following time point (the third and fourth models also included random intercepts).

As a first step for each model, a restricted model (model A) included job strain and wave (the time indicator variable) as independent variables. Following this, a full model (model B) included all covariates to adjust for important potential confounding factors. All of the MLMs used all of the data (i.e., observations) available for the analyses. The models were tested separately for males and females given the suggestion in the prior literature that an

association may differ by sex (i.e., Eek & Östergren, 2009; Klingberg et al., 2019; Niskanen et al., 2017; Solovieva et al., 2013).

4.6 Results

Descriptive statistics on job strain and BMI scores for females and males, by wave, are shown in Tables 4.4 and 4.5. For both sexes, the average BMI was within the overweight range at every wave, and it increased every four years, with the smallest increase observed from wave three to wave four. Detailed descriptive statistics for the current sample, including covariates, are provided in the general methods chapter (see Chapter 2).

Table 4.4*Descriptive Statistics for Males BMI and Proportions Reporting Job Strain Across All Waves*

Variable	BMI score			
Wave	1 (N=1,130)	2 (N=1,030)	3 (N=976)	4 (N=700)
BMI (M/SD)	26.94 (4.49)	27.38 (4.26)	27.72 (4.43)	27.82 (4.12)
Job strain (%)	239/1,130 21.15%	151/1,030 14.67%	155/976 15.88%	97/700 13.85%

Table 4.5*Descriptive Statistics for Females BMI and Proportions Reporting Job Strain Across All**Waves*

Variable	BMI score			
Wave	1 (N=1,141)	2 (N=1,076)	3 (N=1,021)	4 (N=745)
BMI (M/SD)	25.81 (5.45)	26.52 (5.59)	27.07 (5.56)	27.43 (5.74)
Job strain (%)	278/1,141 24.36%	200/1,076 18.58%	109/1,021 10.68%	152/745 20.40%

4.6.1 Multi-Level Mixed Model Sample Differences

Compared with the general random and fixed effects models, the selection of participants by analysis type differed slightly in the baseline job strain and the lagged job strain models (i.e., to be included in the baseline job strain model, participants were required to have job strain data at wave one, but this was not the case for other models, in which participants could be included by the model flexibly across waves). The largest sample was in the general random effects and fixed effects model, which consisted of 3,252 observations from 1,062 male participants and 3,233 observations from 1,168 female participants. The baseline job strain model analysed 3,184 observations from 1,030 male participants and 3,011 observations from 1,055 female participants. Because the lagged job strain analysis excluded BMI at wave one, these models were smaller, analysing 2,404 observations from 1,019 male participants and 2,375 observations from 1,072 female participants.

4.6.1.1 Null Model Across Time

To investigate the change in BMI in the current sample across time, random effects models were run predicting BMI from each wave of the PATH study separately by sex. For females and males (see Tables 4.6 and 4.7, respectively), the significant Wald chi-test indicated that there was enough between-person variation in BMI at the intercept to justify the use of an MLM with a random intercept.

Modelling BMI over the 12 years showed that there was little intra-individual variance in BMI ($[\.38/17.28]100=2.19\%$ of the variance in BMI occurred across the four waves for males, and $[\.68/27.60]100=2.46\%$ of the variance in BMI occurred across the four waves for females), and observing the between-person variance showed that the variation at the intercept accounted for the largest portion of variance in BMI. That is, the majority of variation in BMI was between people at baseline ($[15.39/17.28]100=89.06\%$ of the variance in BMI occurred at the intercept for males, and $[24.53/27.60]100=88.87\%$ of the variance in BMI occurred at the intercept for females).

Table 4.6

Males: Modelling BMI Across All Waves: Random Intercept Model

Male		B	SE	p	CI95	
Wave	2	0.391	0.080	<.001	.233	.549
	3	0.708	0.092	<.001	.527	.888
	4	1.003	0.117	<.001	.773	1.234
Model constant		27.003	0.136	<.001	26.74	27.270
		2				
Total		3252,				
Observations, N		1062				
Variance	Wave	0.38				
	Cons.	15.39				
	Resid.	1.51				
Wald chi-test		3570.45		<.001		

Table 4.7*Females: Modelling BMI Across All Waves: Random Intercept Model*

Female		B	SE	p	CI95	
Wave	2	0.63	0.091	<.001	0.45	0.80
	3	1.30	0.101	<.001	1.11	1.50
	4	1.84	0.130	<.001	1.59	2.10
Model constant		25.8	0.162	<.001	25.5	26.1
Total		3233,				
Observations, N		1168				
Variance	Wave	.68				
	Cons.	24.53				
	Resid.	2.39				
Wald chi-test		3652.90			<.001	

4.6.1.2 General Random Effects Model**4.6.1.2.1 Main Effects**

The first model, a random effects model (allowing a random intercept), examined a general association of job strain with BMI over the four waves and found no evidence for a relationship between these variables in males or females (see model A in Tables 4.8 and 4.9). In the initial models (model A), job strain was not significantly associated with BMI, but the time indicator variable (wave) displayed a significant and cumulatively increasing association with BMI in both males and females, although estimates of the association were larger for females than for males. All relevant covariates were included in model B, and consistent with model A, no association was shown between job strain and BMI over time.

4.6.1.2.2 Covariates

In the adjusted model B, time (wave) was still significantly associated with BMI in a cumulative manner, with slight attenuation of the estimates in both sexes. In females, current smoking was associated with lower BMI, and for both males and females, greater education and higher physical health (RAND-PHC) were associated with lower BMI. While there was limited evidence that moderate amounts of exercise were associated with lower BMI for males, moderate exercise for females was associated with lower BMI, and participating in

greater amounts of exercise per week was more strongly associated with lower BMI for males and females when compared with those engaging in low levels of exercise. Having children, experiencing financial problems, mental health, and job hours per week demonstrated no association with BMI over time in either males or females.

Table 4.8

Males: Association of Job Strain with BMI Across All Waves: Random Intercept Model

Male		Model A				Model B			
		B	p	CI95		B	p	CI95	
Job strain		−0.098	0.312	−0.287	0.092	−0.120	0.215	−0.309	0.069
Wave	2	0.454	<.000	0.312	0.597	0.434	<.000	0.292	0.576
	3	0.810	<.000	0.668	0.952	0.763	<.000	0.620	0.906
	4	1.037	<.000	0.875	1.199	0.962	<.000	0.797	1.128
Smoke	No								
	Yes					−0.737	0.150	<.000	−1.031
Children	No								
	Yes					−0.032	0.231	0.888	−0.485
Exercise	0								
	1					−0.153	0.069	−0.318	0.012
	2					−0.597	<.000	−0.796	−0.398
Finance problems	No								
	Yes					0.043	0.658	−0.147	0.233
RAND-MHC						0.002	0.714	−0.008	0.012
RAND-PHC						−0.024	<.000	−0.036	−0.012
Education (years)						−0.230	<.000	−0.337	−0.123
Job hours						−0.001	0.866	−0.007	0.006
Model constant		26.840	<.000	26.583	27.098	31.822	<.000	30.058	33.587
Total Observation,		3,252,				3,252,			
N		1,062				1,062			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hours of vigorous exercise; 2=>1.5 hours of vigorous exercise.

Table 4.9*Females: Association of Job Strain with BMI Across All Waves: Random Intercept Model*

Female		Model A				Model B			
		B	p	CI95		B	p	CI95	
Job strain		-0.042	0.703	-0.260	0.176	-0.066	0.543	-0.281	0.148
Wave	2	0.600	<.000	0.410	0.790	0.585	<.000	0.398	0.773
	3	1.269	<.000	1.079	1.459	1.128	<.000	0.938	1.318
	4	1.787	<.000	1.569	2.004	1.586	<.000	1.368	1.805
Smoke	No								
	Yes					-1.175	<.000	-1.557	-0.793
Children	No								
	Yes					0.182	0.630	-0.557	0.920
Exercise	0								
	1					-0.241	0.009	-0.423	-0.059
	2					-0.678	<.000	-0.937	-0.418
Finance problems	No								
	Yes					-0.077	0.539	-0.325	0.170
RAND-MHC						0.004	0.544	-0.008	0.016
RAND-PHC						-0.059	<.000	-0.073	-0.046
Education hours						-0.408	<.000	-0.544	-0.272
Job hours						0.002	0.620	-0.005	0.009
Model constant		25.844	<.000	25.507	16.180	34.986	<.000	32.844	37.128
Total Observation,		3,233,				3,233,			
N		1,168				1,168			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hours of vigorous exercise; 2=>1.5 hours of vigorous exercise.

4.6.1.3 Fixed-Effects Model

4.6.1.3.1 Main Effects

The second model, a fixed effects model, examined changes in one variable in association with changes in the others. This showed a nonsignificant association between changes in job strain with changes in BMI over time for both males and females (see Tables 4.10 and 4.11) across both models with and without covariates (models A and B).

4.6.1.3.2 Covariates

The time index variable (wave) demonstrated an increasingly larger association per wave for both models, and although almost no attenuation of the estimates was observed with the addition of covariates in males, some slight attenuation was observed for model B in females. Model B showed that for males and females, changes in smoking status were significantly associated with changes in BMI, such that when individuals reported being a current smoker, they had a lower BMI. In males and females, better physical health was associated with decreased BMI. Moderate amounts of exercise were not associated with lower BMI (compared with engaging in low levels of exercise per week) in females or males. However, across males and females, changes in large amounts of exercise and exercise intensity were associated with lower BMI. Because education was time-invariant (set from wave two of the data), it was omitted from the analysis. Changes in having children, job hours, and mental health were not associated with changes in males' or females' BMI over the four waves.

Table 4.10

Change in Males' BMI as a Function of the Change in Job Strain (and Covariates) Over the Four Waves: Fixed Effects Model

		Model A				Model B			
Male		B	p	CI95		B	p	CI95	
Job strain		-0.139	0.162	-0.333	0.056	-0.149	0.131	-0.344	0.045
Wave	2	0.451	<.000	0.308	0.594	0.427	<.000	0.284	0.569
	3	0.809	<.000	0.666	0.952	0.762	<.000	0.618	0.906
	4	1.047	<.000	0.884	1.210	0.967	<.000	0.800	1.134
Smoke	No								
	Yes					-0.666	<.000	-0.987	-0.345
Children	No								
	Yes					-0.006	0.984	-0.617	0.604
Exercise	0								
	1					-0.083	0.337	-0.252	0.086
	2					-0.523	<.000	-0.729	-0.316
Finance problems	No								
	Yes					-0.019	0.851	-0.214	0.177
RAND-MHC						0.001	0.887	-0.009	0.011
RAND-PHC						-0.015	0.020	-0.027	-0.002
Education						(omitted)			
Job hours						-0.004	0.222	-0.011	0.003
Model constant		26.803	<.000	26.692	26.915	28.046	<.000	27.259	28.832
Total observation,		3,252,				3,252,			
N		1,062				1,062			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hrs of vigorous exercise; 2=>1.5 hours of vigorous exercise.

Table 4.11

Change in Females' BMI as a Function of the Change in Job Strain (and Covariates) Over the Four Waves: Fixed-Effects Model

		Model A				Model B			
Female		B	p	CI95		B	p	CI95	
Job strain		-0.029	0.798	-0.253	0.195	-0.031	0.783	-0.251	0.189
Wave	2	0.607	<.000	0.416	0.798	0.600	<.000	0.411	0.789
	3	1.286	<.000	1.094	1.478	1.169	<.000	0.977	1.360
	4	1.807	<.000	1.588	2.027	1.626	<.000	1.405	1.846
Smoke	No								
	Yes					-1.248	<.000	-1.667	-0.829
Children	No								
	Yes					0.363	0.517	-0.736	1.462
Exercise	0								
	1					-0.176	0.063	-0.362	0.009
	2					-0.519	<.000	-0.788	-0.251
Finance problems	No								
	Yes					-0.138	0.291	-0.394	0.118
RAND-MHC						0.004	0.575	-0.009	0.016
RAND-PHC						-0.046	<.000	-0.060	-0.032
Education						(omitted)			
Job hours						-0.002	0.650	-0.009	0.006
Model constant		25.782	<.000	25.626	25.937	28.402	<.000	27.525	29.279
Total observation,		3,233,				3,233,			
N		1,168				1,168			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hours of vigorous exercise; 2=>1.5 hours of vigorous exercise.

4.6.1.4 Baseline Job Strain Model

4.6.1.4.1 Main Effects

A third model, a random effects model predicting BMI over the four waves of data from baseline job strain (with a random intercept), was carried out. While the beta-coefficient for job strain had increased in size notably in comparison with the random and fixed effects models above, the size of the standard error similarly increased, and this model displayed no significant association between baseline job-strain and BMI modelled over time in males or females (see Tables 4.12 and 4.13) in either model A or B.

4.6.1.4.2 Covariates

The covariates were time varying (not set at baseline like job strain). The time-index variable (wave) again demonstrated significant associations with BMI, with a pattern of increasing association with BMI across the length of the study in both males and females. Smoking was significantly associated with lower BMI over time, while greater physical health and education were related to lower BMI across both males and females. Similarly, high levels of exercise showed significant associations with lower BMI, though having children, experiencing finance problems, mental health and job hours did not show associations with BMI in males or females.

Table 4.12*Males' BMI Over Time as a Function of Job Strain at Baseline: Random Effects Model*

		Model A				Model B			
Male		B	p	CI95		B	p	CI95	
Baseline job strain		0.435	0.139	-0.142	1.011	0.350	0.225	-0.216	0.916
Wave	2	0.464	<.000	0.321	0.606	0.446	<.000	0.304	0.588
	3	0.812	<.000	0.669	0.955	0.766	<.000	0.623	0.910
	4	1.022	<.000	0.859	1.184	0.955	<.000	0.789	1.121
Smoke	No								
	Yes					-0.700	<.000	-0.995	-0.404
Children	No								
	Yes					-0.063	0.786	-0.517	0.392
Exercise	0								
	1					-0.152	0.075	-0.319	0.015
	2					-0.603	<.000	-0.804	-0.402
Finance problems	No								
	Yes					0.056	0.567	-0.136	0.248
RAND-MHC						0.003	0.547	-0.007	0.013
RAND-PHC						-0.023	<.000	-0.035	-0.011
Education						-0.219	<.000	-0.325	-0.114
Job hours						-0.001	0.768	-0.008	0.006
Model constant		26.681	<.000	26.401	26.960	31.417	<.000	29.653	33.181
Total observation,		3,184,				3,184,			
N		1,030				1,030			

Note. Exercise hours per week: 0= <1.5 hrs of moderate exercise; 1= >1.5 hrs of moderate exercise, but <1.5 hrs of vigorous exercise; 2= >1.5 hours vigorous exercise.

Table 4.13*Females' BMI as a Function of Job Strain at Baseline: Random Effects Model*

		Model A				Model B			
Female		B	p	CI95		B	p	CI95	
Baseline job strain		-0.196	0.605	-0.941	0.548	-0.257	0.483	-0.977	0.462
Wave	2	0.610	<.000	0.419	0.802	0.603	<.000	0.414	0.792
	3	1.279	<.000	1.087	1.471	1.151	<.000	0.960	1.343
	4	1.748	<.000	1.527	1.970	1.559	<.000	1.336	1.782
Smoke	No								
	Yes					-1.154	<.000	-1.544	-0.763
Children	No								
	Yes					0.190	0.630	-0.582	0.962
Exercise	0								
	1					-0.295	0.002	-0.482	-0.109
	2					-0.712	<.000	-0.979	-0.445
Finance problems	No								
	Yes					-0.057	0.659	-0.311	0.196
RAND-MHC						0.003	0.683	-0.010	0.015
RAND-PHC						-0.057	<.000	-0.071	-0.043
Education						-0.377	<.000	-0.520	-0.233
Job hours						0.001	0.729	-0.006	0.009
Model constant		25.852	<.000	25.461	26.242	34.537	<.000	32.270	36.805
Total observation,		3011,				3011,			
N		1055				1055			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hours of vigorous exercise; 2=>1.5 hours of vigorous exercise.

4.6.1.5 Lagged Job Strain Model

4.6.1.5.1 Main Effects

The final model, a lagged longitudinal model with a random intercept, analysed the association between job strain at a prior wave with BMI at a subsequent wave, providing an average estimate across two lags (although there were three available lags from four data points, one was used as a reference lag in the model). The restricted model A demonstrated no significant association between prior job strain and subsequent BMI in males or females (see Tables 4.14 and 4.15). For females, this null result was also observed with the inclusion of relevant covariates at model B. At model B, for males, the significance of the coefficient for job strain was below .1, a liberal alpha level. However, given that this is a liberal alpha and no significance was demonstrated in the restricted model A, the evidence is not suggestive of a significant relationship.

4.6.1.5.2 Covariates

The time index variable (wave) demonstrated significant associations with BMI, showing a pattern of decreasing association between the prior wave and BMI four years later in both males and females. Although all lags were equally spaced at four years, the size of the association decreased from the first lag (from wave two to three) to the second lag (from wave three to four). Smoking at a prior wave was significantly associated with decreased BMI at the subsequent wave, while higher levels of physical health and education were related to lower BMI at the subsequent wave for both males and females. Similarly, higher levels of exercise showed significant associations with lower BMI across the time lag for males and females, although moderate exercise demonstrated a significant association with decreased BMI in males, but not females. Having children, experiencing finance problems, mental health, and job hours did not demonstrate significant associations with subsequent BMI.

Table 4.14*Association of Males' BMI with Job Strain Four Years Earlier: Lagged Job Strain Model*

Male		Model A				Model B			
		B	p	CI95		B	p	CI95	
Lagged job strain		0.157	0.132	-0.047	0.361	0.174	0.091	-0.028	0.375
Wave	2	-0.596	<.000	-0.744	-0.448	-0.544	<.000	-0.693	-0.394
	3	-0.239	0.001	-0.383	-0.095	-0.209	0.004	-0.353	-0.066
	4	(omitted)				(omitted)			
Smoke	No								
	Yes					-0.777	<.000	-1.144	-0.411
Children	No								
	Yes					-0.005	0.984	-0.514	0.504
Exercise	0								
	1					-0.149	0.121	-0.338	0.039
	2					-0.642	<.000	-0.874	-0.410
Finance problems	No								
	Yes					-0.012	0.918	-0.242	0.218
RAND-MHC						0.001	0.859	-0.010	0.012
RAND-PHC						-0.027	<.000	-0.041	-0.014
Education						-0.230	<.000	-0.341	-0.118
Job hours						-0.004	0.258	-0.012	0.003
Model constant		27.822	<.000	27.553	28.091	33.128	<.000	31.272	34.985
Total observation,		2,404,				2,404,			
N		1,019				1,019			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hours of vigorous exercise; 2=>1.5 hours of vigorous exercise.

Table 4.15*Association of Females' BMI with Job Strain Four Years Earlier: Lagged Job Strain Model*

Female		Model A				Model B			
		B	p	CI95		B	p	CI95	
Lagged job strain		0.175	0.158	-0.068	0.418	0.191	0.115	-0.047	0.429
Wave	2	-1.220	<.000	-1.413	-1.028	-1.069	<.000	-1.264	-0.874
	3	-0.519	<.000	-0.705	-0.334	-0.474	<.000	-0.656	-0.291
	4	(omitted)				(omitted)			
Smoke	No								
	Yes					-0.926	<.000	-1.376	-0.476
Children	No								
	Yes					0.140	0.735	-0.673	0.953
Exercise	0								
	1					-0.216	0.040	-0.423	-0.010
	2					-0.818	<.000	-1.107	-0.528
Finance problems	No								
	Yes					0.088	0.556	-0.206	0.383
RAND-MHC						0.003	0.698	-0.011	0.017
RAND-PHC						-0.058	<.000	-0.073	-0.042
Education						-0.356	<.000	-0.503	-0.209
Job hours						0.002	0.697	-0.007	0.010
Model constant		27.598	<.000	27.240	27.956	35.725	<.000	33.404	38.045
Total observation,		2,375,				2,375,			
N		1,072				1,072			

Note. Exercise hours per week: 0=<1.5 hours of moderate exercise; 1=>1.5 hours of moderate exercise, but <1.5 hours of vigorous exercise; 2=>1.5 hours of vigorous exercise.

4.7 Discussion

The analyses and research questions addressed in this chapter follow a review of past longitudinal studies investigating job strain and BMI over time that identified several limitations in the existing research. The review suggested that further research would benefit from investigating more modest BMI change over time, the use of more sensitive longitudinal modelling techniques, the analysis of changes over time, and the separation of males and females in analyses. Further, the small number of studies conducted in general, and the inconsistent findings, suggests that further research is needed to clarify the existing evidence. This review, combined with considerations of the slow-developing nature of BMI over time and the lack of any firm support for an association in the previous cross-sectional analyses conducted in Chapter 3, formed the backdrop for the current analyses. These analyses used four waves of longitudinal data collected over 12 years to explore, more comprehensively than prior analyses, whether job strain is associated with BMI outcomes over time. Despite thorough investigation of the conceptual and theoretical possibilities of a relationship between job strain and BMI outcomes over time, no evidence for such a relationship was found within any of the analyses conducted in this chapter (although there was evidence for other covariates being associated with BMI over time).

4.7.1 Job Strain and BMI Over Time

A range of four models, ordered from simpler to more complex, was adopted to use the available longitudinal data to explore a potential association between job strain and BMI outcomes over time. The first general random effects model that was tested pooled all of the available data (results shown in Table 4.7 for males and Table 4.8 for females) and examined reports of job strain in association with BMI levels (allowing individual BMI trajectories to begin at differing points, i.e., the random intercept) across the four waves. These models did not show a significant association between job strain and BMI across the four waves (12 years) of

follow-up for males or females. The main strengths of these models included the increased power afforded by multiple observations from each participant and the ability to measure the correlations between observations over time. The literature review identified that a relationship between job strain and BMI outcomes is likely to be very small (if it exists at all), and that the lack of power of previous studies may, in part, explain the nonsignificant effects observed (Bersset et al., 2011; Nyberg et al., 2012; Kivimäki et al., 2015; Wardle et al., 2011). It is possible that the current analyses were still underpowered. Despite this, the general random effects model and the subsequent longitudinal models in this chapter are more powerful than their cross-sectional counterparts and prior longitudinal studies using less sensitive analytic techniques. However, despite the additional power and sensitivity, no evidence was found for an association between job strain and BMI outcomes over time.

While the general random effects model increased the power available to detect an effect, the hypothesis that a change in the experience of job strain may be related to a change in BMI levels was also tested. This possibility has previously been assessed by two studies—one meta-analysis with just two data points (Kivimäki et al., 2015) and the other using four data points (Azagba & Sharaf, 2012)—although both studies combined sexes within the analyses and examined a shorter follow-up period than the current study. Thus, to examine changes more specifically over time in the analytical model, fixed effects analysis was conducted (results shown in Table 4.9 for males and Table 4.10 for females), which included only time-varying variables. The results of the fixed effects analyses did not provide evidence for an association between change in the experience of job strain with changes in males' or females' BMI over time. This finding is consistent with the results of the general random effects analyses and the results of the prior fixed effects analyses conducted by Kivimäki et al. (2015) and Azagba and Sharaf (2012).

A key strength of fixed effects models examining changes in exposure with contemporaneous changes in outcomes is the ability to take a step closer to establishing that these two factors are concurrently, and potentially, causally related. However, there was no evidence that this was the case in relation to job strain and BMI. Similar to the current results, Nyberg et al. (2012) noted an absence of evidence to suspect a causal relationship between job strain, especially job strain at baseline, and subsequent BMI approximately four years later. However, they found that those who reported job strain at follow-up were statistically more likely to concurrently report being obese. Potential explanations for this contrast with the current findings include the type of analysis techniques used: Nyberg et al. (2012) used logistic regression analyses, which, when reported in Kivimäki et al. (2015), contrasted with the null findings of a fixed effects analysis also reported in that study. While Nyberg et al., Kivimäki et al., and Azagba and Sharaf (2012) controlled for sex rather than separate their analyses by sex, the present null results do not suggest differences between males or females, thus contributing original information and context to these investigations.

The PATH study's long follow-up period (12 years) is a particular strength. The long duration allowed for an alternative consideration of the potential association between job strain and BMI—specifically, that an experience of job strain at baseline (at wave one, when participants were aged 40–44) might be associated with subsequent BMI over a 12-year period. This analytical model specifically explored whether initial job strain is particularly important, and whether it might predict BMI levels across a lengthy period, as evidenced in studies such as Klingberg et al. (2019) and Brunner et al. (2007). This model begins to explore the notion that job strain might have a predictive or causal effect on future BMI by examining whether an initial experience of job strain might play out over a long period and be observed in association with future BMI. Given the lack of studies with data on job strain at both baseline and follow-up, this model is comparable to much of the literature on job strain and BMI outcomes over time,

whereby job strain is measured only at baseline and analysed in association with change or changes in BMI over time. Some studies reported positive associations between job strain and its components at baseline with subsequent BMI outcomes (e.g., Eek & Östergren, 2009; Kivimäki et al., 2006; Klingberg et al., 2019). However, in the current study, which used a more sensitive longitudinal model allowing baseline BMI to vary among individuals in the analysis (the random intercept), no association between an experience of job strain at baseline resulted in an association with BMI over the subsequent 12 years in males or females. This was reflected in both the restricted model (model A) and the full model with all relevant covariates included (model B).

The four-year spacing and structure of data collection (i.e., job strain and BMI were both sampled at each of the four waves) in the PATH study presented an opportunity to conduct a lagged analysis—a model not tested in the literature reviewed. This examined whether BMI might be influenced by a prior experience of job strain four years earlier. The analyses showed that, for both males and females, no relationship was evident between a report of job strain at a prior wave and BMI four years later. This model extended the information generated by testing the baseline job strain model, as the results of each together showed no evidence for a relationship subsequent to an experience of job strain either four or 12 years later. While some prior evidence suggests that studies with longer follow-up periods are more likely to find an association between job strain and BMI (Wardle et al., 2011), neither of the previous three models examining associations with BMI over a long follow-up period (12 years) found evidence that this was the case. While the random and fixed effects models essentially analysed job strain concurrently with BMI, the baseline model was restricted by the experience, or absence, of job strain at the first wave only. The lagged model was able to use reports of job strain at waves one, two, and three. While the follow-up for the baseline job strain model was over the entirety of the study (12 years), in the lagged analyses, job strain was effectively

examined for an average association with BMI over a shorter follow-up period of four years. Importantly, neither length of follow-up returned evidence for an association of job strain with BMI outcomes. Further, the length of follow-up in the lagged analyses here is somewhat comparable to the 4.75-year average follow-up in the meta-analyses by Kivimäki et al. (2015), who also reported that the length of follow-up was not significantly related to an association of job strain with BMI over time.

Overall, the results of the four longitudinal models conducted in this chapter did not demonstrate evidence for a longitudinal relationship between job strain and BMI over the study period. This was despite the comprehensive investigation into how such a relationship may present. At a general/pooled level, no association was found between job strain and BMI over a 12-year period, and modifying the analysis to examine only change in job strain with change in BMI also did not find a relationship. Exploring the temporal elements and timeframes in which BMI may be associated with the experience of job strain also demonstrated no significant associations with either the baseline report of job strain and BMI over the subsequent 12-year period, or with any average association of job strain and subsequent outcomes in BMI four years later.

4.7.1.1 Covariates

Each fully adjusted analysis (model B for each of the four differing MLM analyses) included a range of demographic and other covariates to control for confounding associations with BMI. Across all four analysis types (at model B), smoking and education were consistent significant predictors of BMI outcomes over time for females, with smoking and higher levels of education associated with lower BMI over time. This was also found for males, except for a nonsignificant association between smoking and BMI over time in the general random effects model. As expected, the association for males and females who engaged in vigorous exercise of more than 1.5 hours per week was consistently and strongly associated with lower BMI, and

while moderate levels of exercise were also largely associated with lower BMI in females, there was less evidence that this was the case for males. For females and males, better physical health was consistently significantly associated with relatively small decreases in BMI over time, relative to those with worse physical health scores. No evidence was found for an association of BMI with having children, working hours per week, experiencing financial difficulties, and mental health in any of the four models.

4.7.2 Strengths, Limitations, and Implications

When appraising the quality of the current study, there are several strengths and original contributions to the literature that must be noted. The first of these concerns the rich structure of the PATH dataset, which offers four data points to be analysed and separates each analysis by sex. The benefits of multiple data points have been maximised with the use of multilevel modelling analytic techniques. Although longitudinal methods have been previously employed in prior studies of job strain and BMI, the number of data points in such analyses has rarely exceeded two, and most studies have employed modelling approaches that are constrained in their ability to examine change within variables or relationships. The current models have allowed the exploration of both within- and between-person variance in the relationship between job strain and BMI, showing that the variance of BMI in male and female individuals over this 12-year study was low, and there was no evidence for a relationship between within-person change in job strain and change in BMI over time (e.g., in the fixed effects models). The MLM analyses selected, combined with the four data points over 12 years, increased the power and sensitivity to model the estimates produced by each analysis.

A second strength of the current study is the comprehensive set of four concurrent models analysed. While the exploration of job strain and BMI outcomes has previously been reported using random and fixed effects MLM analyses concurrently (albeit in just two studies), the inclusion of the lagged MLM analyses is an original contribution. Modelling different

approaches/analyses using the same dataset reduces doubt over whether any variation in findings is the result of differences between datasets (i.e., in measurement, sample, or analysis). The comparisons between the baseline and lagged job strain models also offer insights into whether differing lengths of follow-up affect the results, as suggested by some previous studies and reviews (Klingberg et al., 2019; Solovieva et al., 2013; Wardle et al., 2011). For example, the lagged analysis follow-up is averaged over two four-year change cycles, whereas the baseline job strain model uses all 12 years of follow-up data on BMI. Given that both models returned null results, the consistency could be interpreted as evidence that follow-up length is not influential (although further research explicitly addressing follow-up length would better address this question).

To summarise, the strengths of the current study include the availability of four data points, measurements of both job strain and BMI at each data point, the use of sensitive longitudinal MLM analyses, separate analyses by sex, and a longer-than-average follow-up period. While a variety of these features can be found in previous studies, the specific combination of strengths in the present study goes some way towards providing clarity and contributing new insights to the established body of literature. Despite the null results, the comprehensive approach has enabled further discussion around the conceptual and theoretical nature of a relationship between job strain and BMI over time, including being able to examine more complex temporal hypotheses such as job strain preceding or co-occurring with BMI outcomes and changes.

A final notable feature of the current chapter is that this is the first set of longitudinal population-based analyses reporting on job strain and BMI over time in an Australian population. While two cross-sectional analyses have previously been undertaken in Australian populations—specifically, in South Australian and Victorian population samples (Bean et al., 2015; Ostry et al., 2006)—this is the first longitudinal research to use Australian data—in

particular, data from the Canberra region—to examine job strain and BMI over time. The Canberra region has a relatively high SES profile compared with the rest of Australia: a higher percentage of individuals have completed higher education; the average income is higher; a higher percentage of working individuals are employed full time; and the proportion of professional workers and those who work 40 or more hours per week is slightly higher (ABS, 2018).

These characteristics demonstrate a high SES profile and therefore may present bias when trying to extend the results obtained here to the greater Australian population (given that these higher SES characteristics may buffer any effect of job strain on BMI outcomes). In differing samples that are more representative of the Australian population, or in Australian samples with lower SES profiles, job strain may be more important for BMI outcomes. Evidence of this possibility comes from other studies demonstrating associations of work stress and occupational factors with higher BMI over time in a varied Australian sample (Magee et al., 2010) and a nationally representative population sample (Taouk et al., 2019). While it is beyond the scope of the present study to explore differences based on SES profile, there is a need for further analysis of job strain and BMI outcomes in varied Australian samples, and for the general population.

In considering the limitations of the present study, a larger sample size would help to improve statistical power and accuracy. Studies such as Brunner et al. (2007), Eek and Östergren (2009), Kivimäki et al. (2006), Nyberg et al. (2012), and Fujishiro et al. (2015), who found positive associations, had definitively larger sample sizes than the current study. Indeed, Kivimäki et al. (2015) noted that their longitudinal analyses were likely underpowered with a sample of approximately 40,000 participants. Although the use of more specific analytic methods in the current study helped to overcome the loss of power experienced by having a smaller sample size, increasing the sample size would be desirable for future studies. Similarly,

while the current analyses have maintained many variables as continuous to overcome the loss of information resulting from the use of categorisation (Kivimäki et al., 2006), some studies have further adopted continuous job strain scores (Kivimäki et al., 2006) and undertaken further testing of the individual components of job strain (decision authority and skill discretion, job control, and demands) with BMI (Bean et al., 2015). Although there is preliminary evidence that operationalising variables as continuous is beneficial, this is a consideration for future studies attempting to understand the inconsistencies within the literature.

A final consideration, especially when comparing the present study to past studies, is that the role of baseline BMI was not accounted for in the current study. This is in contrast to some authors (Block et al., 2009; Fujishiro et al., 2015; Kivimäki et al., 2006; Niskanen et al., 2017; Nyberg et al., 2012) who controlled for, or stratified, their analyses by baseline BMI. There is preliminary evidence that participants' initial BMI (BMI at baseline) may moderate an association of job strain with BMI. Several authors have reported significant interactions of job strain with baseline BMI or found significant associations with BMI when the study sample has been stratified by baseline BMI (i.e., Fujishiro et al., 2015; Klingberg et al., 2019; Niskanen et al., 2017; Kivimäki et al., 2006; discussed in more detail in Chapter 6). Thus, although this is not examined in the current chapter, it is an interesting avenue for further examination and potential articulation of a relationship between job strain and BMI outcomes over time (and is explored in Chapter 5).

4.7.3 Conclusions and Implications

This chapter identified several limitations in the past literature on job strain and BMI outcomes over time, including the broad categorisation of BMI thresholds, concerns over low study power, a lack of examination of more than one measurement of change over time, the combination of sex in analyses, the potential importance of follow-up lengths, and discrepant measurement and analytical instrumentation. These were all key limitations that contributed to

uncertainty over whether an association between job strain and BMI over time was indeed present and had potentially been obscured, or whether no association was to be found. Despite addressing these identified concerns where possible in the present analyses, including the use of robust analytical methodology and analysis, and concurrently analysing data on job strain and BMI across different models, the present study found no evidence to support a relationship between job strain and BMI outcomes over time. The results obtained here reflect other studies that have similarly found no, or limited, evidence for an association over time (e.g., Azagba & Sharaf, 2012; Block et al., 2009; Kivimäki et al., 2015; Nyberg et al., 2012). While the current chapter and analyses offer original contributions that provide further insights into the study of job strain and BMI outcomes over time, further research is still required. In particular, findings from research that can assess multiple data points over a lengthy follow-up period with a larger sample size would contribute significantly to the existing literature.

Chapter 5: Does Baseline BMI Affect the Relationship Between Job Strain and BMI Over Time?

5.1 Chapter Summary

Chapter 4 of this thesis set out to answer the broad question of whether an association exists between job strain and BMI over time. The current chapter aims to answer a similar, but distinctly different, research question: is an association between job strain and BMI over time moderated by individuals' BMI at the beginning of the study? In the longitudinal context, this initial BMI measurement is referred to as 'baseline BMI'. For example, a higher baseline BMI or obesity may be a risk factor for greater BMI increase given an experience of job strain. A decision to separate the previous longitudinal analyses chapter from the current chapter was made after a critical appraisal of the existing literature showed that while several studies noted the potential influence of baseline BMI, few had tested this interaction, and of those that had, there were some inconsistent findings. Hence, the current chapter's introduction reviews those studies that explore whether the risk of job strain on future BMI is moderated by initial (baseline) BMI. Overall, the evidence reviewed in this chapter supports the possibility of a moderating effect, warranting further exploration of this interaction.

Methods: The sample used in the current study included 1,130 males and 1,141 females at wave one, 1,030 males and 1,076 females at wave two, 2,976 males and 1,021 females at wave three, and 700 males and 745 females at wave four from the PATH Through Life longitudinal study. Four sets of longitudinal MLMs were conducted in the analyses, mirroring those conducted in the previous chapter (i.e., a general random effects model, a random effects model restricted to baseline job strain, a fixed effects model, and a lagged model that reported on an association between job strain at a prior wave and BMI at a subsequent wave). The four sets of analytic models were tested stratified by sex. All the models examined the interaction

between baseline BMI (modelled both continuously and categorically) and job strain as the focus of the chapter. Potential differences by baseline group were then explored further by conducting separate analyses by baseline BMI category: those normal weight, overweight, or obese at wave one.

Results and discussion: Overall, the analyses found no robust, consistent evidence to suggest that a relationship between job strain and BMI over time is moderated by initial BMI at baseline. While this was the case for both males and females, some weak potential evidence was noted for females. Inconsistencies in the results, cautious interpretation, and statistical limitations are all discussed, as well as how the current chapter's analyses align with the existing research.

5.2 Introduction and Background

A key argument for undertaking the research in this thesis is that existing evidence for a relationship between job strain and BMI is mixed (as discussed in detail in previous chapters). In attempting to explain these mixed findings, some researchers have noted a lack of consideration for baseline BMI and whether it might confound or influence the strength of a relationship between job strain and BMI (e.g., Block et al., 2009; Eek & Östergren, 2009; Fujishiro et al., 2015; Kouvonen et al., 2005; e.g., Nyberg et al., 2012). The reasoning is that an individual's position in the BMI distribution at the start of a period (their baseline BMI in the context of a research study) reflects, at least in part, individual differences in behavioural, physiological, psychological, and environmental determinants of BMI up to that point in time. Over time, these determinants are likely to become relatively stable (especially by mid-life, such as the sample used in the current thesis) and form patterns for how people live and react in the context of stress or strain. This is relevant to the examination of job strain with BMI outcomes over time because some research (Botosaneanu & Liang, 2012; Hoang et al., 2019; Roberts et al., 2007) shows stable/established coping mechanisms (both helpful and unhelpful) that are linked to BMI

outcomes (Tomiyaama, 2019). In particular, this may be the case for individuals towards either end of the BMI distribution (i.e., underweight and obese individuals), where established coping mechanisms seem more likely to entrench or amplify their BMI following a stressful experience (Kivimäki et al., 2006; Tomiyama, 2019).

Individual differences associated with placement in the BMI distribution at baseline may aggregate across individuals to alter the strength of an association between job strain and BMI (at the population level), and thus a main effect might be missed. For example, higher initial (baseline) BMIs may interact with job strain to alter the strength of the association with future BMIs differently from average (or lower) BMIs. Given that some existing studies (Block et al., 2009; Brunner et al., 2007; Fujishiro et al., 2015; Kivimäki et al., 2006; Klingberg et al., 2019) hint at evidence for a moderation of association depending on the lower, middle, or higher end of the baseline BMI spectrum, further investigation is warranted. These studies are reviewed below, and the evidence for an interaction between baseline BMI and job strain is considered.

5.2.1 Do Job Strain and Baseline BMI Interact? Reviewing the Results from Past Studies

The literature on job strain and BMI has long alluded to the potential for an interaction of job strain with baseline BMI and the need for exploration and testing (e.g., Kouvonen et al., 2005). However, there is limited research to date: a review of the literature found only four studies that have tested an interaction between job strain and baseline BMI analytically (Fujishiro et al., 2015; Ishizaki et al., 2008; Kivimäki et al., 2006; Niskanen et al., 2017). Given this, evidence from the components of job strain (job demands and job control) is also considered in this review, and the findings of these studies together inform the state of evidence for the current chapter. Two studies analysing job strain also reported testing an interaction between the job demands and control scales (Ishizaki et al., 2008; Niskanen et al., 2017), while two further studies reported findings from testing these scales only (either in interaction with baseline BMI or in analyses stratified by baseline BMI) (Block et al., 2009; Klingberg et al.,

2019). Each of the six studies also tested for a main effect of job strain in association with BMI over time, and these results were reviewed in Chapter 4.

Fujishiro et al. (2015) analysed data from 52,656 female nurses aged 25–42 at baseline of the Nurses' Health Study II, conducted in the US, and found evidence for an interaction of job strain with baseline BMI. Fujishiro et al. used two measurements of job strain recorded at baseline and follow-up, and focused their investigations on four patterns of job strain over the study: low job strain at baseline and follow-up (used as the reference category), a change from high job strain to low job strain, a change from low job strain to high job strain, and persistently high job strain at baseline and follow-up. In regression analyses, they analysed change in BMI continuously as a function of an interaction between the pattern of job strain over time with continuous BMI at baseline.

Fujishiro et al. (2015) found that those who had higher BMI at baseline and reported job strain persistently at both baseline and follow-up had significantly greater increase in BMI over the study period (although the estimated average change in BMI was very small). However, the findings demonstrated that as BMI at baseline increased, the predicted BMI change over four years was greater. Fujishiro et al. graphed the interaction by the category of job strain pattern, which showed that, up until baseline BMI of approximately 27 (almost the middle of the overweight BMI category), there was a uniform main effect of job strain with BMI increase across the study. However, those with a baseline BMI greater than 27 who reported job strain twice had a greater increase in BMI compared with the other patterns of job strain. Based on the findings of Fujishiro et al., the size of the association with job strain increased as baseline BMI increased and was predicted to be approximately .4 BMI units greater, on average, for females whose baseline BMI was greatest. This indicates that the difference in BMI increase was predicted to be quite modest, even for those higher on the BMI distribution at baseline.

The results of a more recent study by Niskanen et al. (2017) further support a moderating role of baseline BMI on an association of job strain with future BMI increase for females. Niskanen et al. analysed 3,622 female Finnish employees from Helsinki at three time points across 12 years. Job strain was measured at each of the first two data collections, and weight gain was measured between the first and third data collection points (10–12-years follow-up). Similar to Fujishiro et al. (2015), Niskanen et al. examined patterns of job strain in association with major weight gain (defined as a 10% gain from baseline weight) at follow-up. When the sample was separated by those with a BMI less than 25 at baseline (normal weight) and those with a BMI greater than 25 at baseline (overweight and obese combined), an increase in job strain (a change from low job strain at baseline to high job strain at follow-up) significantly predicted a 53% increased likelihood of major weight gain at follow-up for females who were overweight and obese at baseline. This finding was only observed in females with a BMI greater than 25 at baseline, and not among those with a BMI of less than 25 (normal weight BMI).

The findings of Niskanen et al. (2017) and Fujishiro et al. (2015) indicate that baseline BMI may moderate how experiencing job strain may be associated with future BMI increase. Their studies showed that females with higher BMI at baseline may be more vulnerable to BMI increase over time in connection with experiencing job strain, compared with female employees with lower BMIs who also experience job strain. Fujishiro et al. exclusively analysed female nurses, and therefore could not speak to evidence for an interaction of job strain with baseline BMI in males.

However, an earlier study by Kivimäki et al. (2006) reported stronger evidence for an interaction of job strain and baseline BMI in males than in females. They analysed a sample of British civil servants enrolled in the Whitehall study: 5,547 males and 2,418 females aged 35–55 years at the beginning of the study. They tested whether there was an interaction between baseline BMI and a binary yes/no indicator of job strain at baseline with BMI five years later at

follow-up. In separate analyses, they used linear regressions to model the interaction of baseline BMI with a continuous measure of job strain (derived from a modified JCQ). The interaction of baseline BMI with job strain was significant in males such that those who had higher BMI and reported job strain at baseline had greater average BMIs at follow-up. To investigate the interaction more thoroughly, Kivimäki et al. conducted stratified analyses based on separating the sample into quintiles of baseline BMI. Within each quintile, the authors identified those who gained weight and those who lost weight across the study period (indicated by an increase or decrease in BMI from baseline to follow-up). They then estimated the likelihood of weight gain or loss for each of the bottom, middle three (combined), and top baseline BMI quintiles, and contrasted the findings for each.

For males in the top quintile at baseline (BMI>27), a 22% increase in the odds of subsequent weight gain was found for those with higher job strain (i.e., indicated by a job strain score greater than one standard deviation above the average). The sample from the middle three quintiles of baseline BMI showed no significant increase or decrease in the odds of weight gain or loss dependent on job strain. In contrast with males in the highest quintile of baseline BMI, males with a BMI below 22 at baseline (the lowest quintile of baseline BMI) had a 14% increase in the odds of weight loss given high job strain. Thus, the results of Kivimäki et al. (2006) support an interaction of job strain with baseline BMI, showing not only a difference in association between those with average BMIs and those in the higher BMI ranges, but also an opposite association for those of lower BMIs at baseline. This is an interesting finding that lends support to the idea that, especially towards either end of the BMI distribution, a stressful experience such as job strain may be met with individuals engaging in established patterns that may further influence their BMI position (Järvelä-Reijonen et al., 2016; Kivimäki et al., 2006; Nevanperä et al., 2012).

Three of the four studies reported here found evidence that individuals' baseline BMIs may moderate an association of job strain with future BMI increase. Broadly, the studies agree that there is evidence for greater BMI increase among those who are overweight and obese at baseline in connection with experiencing job strain compared to those with more average BMI at baseline. However, there are details among the evidence that do not align between the studies. For example, although Fujishiro et al. (2015) and Niskanen et al. (2017) found some evidence among females, Fujishiro et al. reported a significant interaction for females who experienced job strain at baseline and follow-up, and not for females who only reported job strain at one of the measurement times. In contrast, Niskanen et al. reported a significant interaction specifically among females who were overweight and obese at baseline without job strain, and who then went on to experience job strain at the next measurement. Tests of an interaction for females experiencing high job strain persistently at two measurement occasions were not significant. In contrast to these studies, Kivimäki et al. (2006) did not report any evidence for an interaction of job strain among females, but found evidence among male employees who were overweight and obese at baseline.

Adding to the inconsistencies, Ishizaki et al. (2008) was the only study to report entirely null findings for males and females. Ishizaki et al. also used two measurements each of job strain and BMI taken at baseline and follow-up, and focused their investigation on whether there was evidence for an interaction of baseline BMI with job strain patterns over time. They categorised three groups similar to Fujishiro et al. (2015) and Niskanen et al. (2017): those reporting low job strain at baseline and follow-up, those reporting job strain at only baseline or follow-up (i.e., a change in job strain occurred), and those with high job strain at each measurement time. While Ishizaki et al. did not explicitly test an interaction analytically, they examined whether the job strain patterns were associated with the change in BMI from baseline to follow-up in three baseline BMI categories: those classified as 'slender' at baseline—defined by BMIs more than

one standard deviation below the sex-specific average; those classified as ‘moderate’—defined by BMIs within one standard deviation below and above the average BMI at baseline; and those classified as ‘overweight’—whose BMI at baseline was greater than one standard deviation above the average. Six analyses were carried out in total: three per sex, one within each of the baseline BMI categories. The results indicated that different patterns of job strain were not significantly associated with change in BMI for any of the baseline BMI categories.

Considering the four studies reviewed here, there are obvious inconsistencies in the literature that would benefit from further research. As with the general body of research examining job strain and BMI together, the lack of clear and consistent evidence raises doubts over whether baseline BMI may moderate an association of job strain with future BMI differently depending on higher or lower BMI at the beginning of a study period. While it is difficult to draw clarity from such a limited amount of research, if there is an interaction, the preliminary evidence indicates that those with a higher BMI at the start of a study may be more susceptible to subsequent BMI increase in connection with job strain. Another important consideration is that the size of the interaction appears to be modest: each of the three studies that reported significant findings reported small, weak associations—increases as little as .022 BMI units reported by Fujishiro et al. (2015) (although this estimate increased with increasing baseline BMI). The small anticipated size of an interaction is again similar to the limited evidence in the general body of research on job strain and BMI. Although it is not the focus of this thesis, given the limited research to date on whether job strain interacts with baseline BMI and the need for further clarity, further evidence is examined below from the core components of job strain (job demands and control) in interaction with baseline BMI.

5.2.1.1 Evidence from Job Demands and Job Control in Interaction with Baseline BMI

Klingberg et al. (2019), Niskanen et al. (2017), and Kivimäki et al. (2006), reviewed above, also analysed whether baseline BMI may moderate a relationship of job demands and

control with BMI over time. In their analyses of British civil servants enrolled in the Whitehall study, Kivimäki et al. used linear regressions to model the interaction of baseline BMI with continuous measures of job demands and job control. The interactions of baseline BMI with job control were significant in males such that those who had a higher BMI and reported lower job control at baseline had greater average BMIs at follow-up. In further stratified analyses, Kivimäki et al. reported a 15% increased likelihood for weight gain for those who had been in the highest quintile of BMI at baseline and who reported low job control. Thus, the results of Kivimäki et al. support an interaction of both job strain and low job control with baseline BMI for males. No evidence was found for an interaction with job demands among males, or with any job demands or control variables for females.

Building on the findings of Kivimäki et al. (2006), Block et al. (2009) also tested an interaction of job strain components with baseline BMI on BMI over time. Using a nationally representative sample of mid-life US adults (633 male and 722 female participants aged 25–64 at baseline), Block et al. tested the hypothesis that baseline BMI would moderate the relationship of work stress (measured using the JCQ job demands and control scales) with change in BMI over nine years. Using regression analyses to predict the continuous change in BMI at follow-up, the interaction term they tested was calculated using continuous job demands and the subscales of job control—decision authority and skill discretion—with continuous baseline BMI. These variables were then entered into multiple regression analyses, where Block et al. found that the interaction terms demonstrated that higher job demands in those with higher BMI at baseline were associated with significantly greater average BMI change for both females and males. Further, for males, they found that lower job decision authority and skill discretion were associated with increased BMI change in those whose baseline BMI was higher at the beginning of the study.

There are findings and features of the studies conducted by Kivimäki et al. (2006) and Block et al. (2009) that are easily comparable. For example, both used a continuous construction of job strain in regression analyses, and both had information on the JDC scales only at baseline, and measurements of BMI at both baseline and follow-up. Overall, the overlap in their findings support an interaction of baseline BMI with psychosocial job characteristics for males—in particular, for decreased job control among those who were higher than average in baseline BMI, with an increasing strength of association as baseline BMI increased. While the scale of job control itself was not explicitly tested by Block et al., the direction of the association for each of the subscales of decision authority and skill discretion were the same as that for job control tested by Kivimäki et al. However, in Block et al., higher job demands in males were predictive of increased BMI gain for males who were higher on baseline BMI, and the strength of association was greater than that reported for the job control subscales. In Kivimäki et al., the interaction of job demands with baseline BMI for males was not significant. This was despite job strain—the combination of high job demands and low control—significantly interacting with baseline BMI to be associated with greater BMI increase for males. A comparison of the studies' results is made more difficult because job strain was not tested for an interaction with baseline BMI with later BMI by Block et al. However, given the direction and significant association of each of the constituent scales of job strain—low job control subscales and high job demands—it is likely that job strain would have been significant among the sample of males if tested by Block et al.

The results for females between the studies are also largely consistent in that no interactions were significant except for an interaction of job demands with baseline BMI with increased follow-up BMI in the sample of females analysed by Block et al. (2009). No further evidence for an interaction of psychosocial job characteristics in females (job control or its subscales, and job demands in Kivimäki et al., 2006) was found. Thus, these early studies of an

interaction between job demands and control with baseline BMI found greater evidence for a differential association—an interaction—among males than females.

However, two more recent studies by Klingberg et al. (2019) and Niskanen et al. (2017) reported findings that do not agree with those reported by Kivimäki et al. (2006) and Block et al. (2009). Klingberg et al. and Niskanen et al. also analysed samples of males to test for an interaction of high job demands with baseline BMI on major weight gain at follow-up. While Klingberg et al. did not report evidence for an interaction, Niskanen et al. reported finding a significantly increased risk for major weight gain in males who were normal weight at baseline and reported a decrease in job demands. This significant finding was specific only to males experiencing these conditions. In further analyses, low job control was also analysed for an interaction with baseline BMI, but the results of Klingberg et al. and Niskanen et al. were consistent in finding no evidence for males or females. These findings present further inconsistencies within the evidence available as to how baseline BMI may moderate a relationship of job strain with future BMI for males.

Additionally, the results of Klingberg et al. (2019) and Niskanen et al. (2017) together provide evidence that females' baseline BMI interacts with the components of job strain to be associated with greater BMI increase, further supporting the findings of Fujishiro et al. (2015) (discussed above). In logistic regression analyses, Niskanen et al. (details discussed above) found that an increase in job demands over time predicted a 52% increased likelihood of major weight gain at follow-up. This finding was only observed in females with a BMI greater than 25 at baseline, and not in those of normal weight. Evidence for a similar finding was reported by Klingberg et al., who found that reporting high job demands twice over a 10-year period was significantly associated with a 313% increased likelihood of major weight gain at follow-up, although only for females whose BMI was greater than 25 at baseline, and not for those with a normal-weight BMI at baseline.

The similarities between the studies of Klingberg et al. (2019) and Niskanen et al. (2017), and the consistency of the results, provide extra confidence in the findings. Each study had three measurement points, with job demands and control measured at the first two occasions, and weight gain was calculated from baseline to the final follow-up. The sample sizes were large for both: Klingberg et al. analysed 2,074 females, while Niskanen analysed 3,842 females. Logistic regression analyses were used in both studies, and the outcome—major weight gain—was defined similarly as a 10% increase in body weight at baseline. The stratification of baseline BMI categories was also comparable: a BMI of 25 was used to define the normal weight, and the overweight and obese combined, baseline categories. While the length of follow-up in Niskanen et al. was shorter than in Klingberg et al. (12 years compared to 20 years respectively), both can be considered long follow-ups.

The main discrepancy between the studies was the finding by Klingberg et al. (2019) that persistently high job demands at two measurement points significantly predicted major weight gain, whereas Niskanen et al. (2017) reported that only high job demands at the second measurement point (an increase from baseline) was significantly associated with major weight gain. However, this was specifically when analysing those with a baseline BMI greater than 25, because in analyses with the full sample, persistently high job demands were predictive of major weight gain across the BMI distribution for females. Despite this discrepancy, the sum of the findings from Klingberg et al., Niskanen et al., and Block et al. (2009) support the possibility of an interaction of high job demands with baseline BMI. In lieu of clear and consistent findings from examinations of job strain explicitly, evidence that this core component of job strain interacts with baseline BMI in association with later BMI over time provides another reason to investigate this possibility with job strain.

5.2.2 Potential Reasons for the Inconsistencies

Differences between the studies may have contributed to the inconsistencies in the results. The operationalisation of job strain, its components, and the job strain measure differed between the studies, thereby presenting a confound that may have influenced the results reported. Block et al. (2009) and Kivimäki et al. (2006) operationalised JDC scales as continuous scores in analyses, although the method differed in each: Kivimäki et al. subtracted scores on the job demands scale from the job control scale to create a strain variable, and Block et al. used the mean scores of the JDC scales continuously. Ishizaki et al. (2008) also used a continuous ratio construction of job strain (job demands/job control) and then dichotomised this variable at the median to indicate high and low job strain categories. Fujishiro et al. (2015), Klingberg et al. (2019) and Niskanen et al. (2017) used traditional dichotomised median splits of job control and demands to derive categorical job strain, job demands, and control variables. Thus, four studies used categorical JDC variables and two studies operationalised the JDC scales continuously within analyses; however, few of the studies had a consistent construction for direct comparison. In addition, the structure of the job strain measure varied between the studies. For example, Klingberg et al. used four- and six-item scales to measure job demands and control, while Niskanen et al. used a version containing nine questions to measure each scale, and Block et al. used five- and nine-item scales to measure job demands and control. While each was validated, these are examples of potential confounding factors when examining the inconsistencies among the findings.

5.2.3 Summary of the Literature

A comparison of the results of the past studies reviewed highlights both similarities and differences. Regarding sex, the earlier studies of Kivimäki et al. (2006) and Block et al. (2009) found more consistent evidence for an interaction of job strain and each of its components, with baseline BMI, in males rather than females. However, the later studies conducted by Fujishiro et

al. (2015), Niskanen et al. (2017), and Klingberg et al. (2019) showed more consistent evidence that baseline BMI may moderate a relationship of job strain, and its component scale (high job demands), with future BMI for females. There appears to be some inconsistency regarding whether a specific pattern of job strain or job demands over time (i.e., an increase or persistent job strain/high job demands) is associated with future BMI differently depending on baseline BMI.

It is more difficult to reconcile the evidence for an interaction of job strain and its components among males. Ishizaki et al. (2008) showed no significant differences for males in the association of job strain pattern with change in BMI by differing baseline BMIs. This is inconsistent with the results of Kivimäki et al. (2006) and Block et al. (2009), who largely found support for an interaction among males (apart from an interaction with job demands reported in Kivimäki et al.). The fact that these earlier studies examined the association of job strain and JDC characteristics at just one point in time with subsequent BMI change, rather than patterns of change among job strain over time (as in Ishizaki et al.) may go some way to understanding the inconsistency in the results. However, when considering the results of Niskanen (2017), who found that males who were normal weight at baseline and who experienced a decrease in job demands over time were at increased risk for major weight gain, it appears that the consistency of the results is less clear for males than for females.

An important similarity among the results of the studies is that where an interaction was found for those higher in baseline BMI, it was positive. This suggests that those who have higher BMI at baseline may be more susceptible to larger increases over time given an experience of job strain or its components. However, based on the limited information available, the size of any interaction is likely to be small. Kivimäki et al. (2006) did not indicate the size of an interaction—only the significance and likelihood of BMI increase and decrease—but Block et al. (2009) reported a BMI increase that ranged from .07 to .18 (dependent upon the sub-scale) per

every BMI unit above average, and Fujishiro et al. (2015) noted that the significant estimate for the interaction of job strain and baseline BMI was .022 BMI units. Thus, evidence indicates that if an interaction is present, it is very small in size.

However, when Klingberg et al. (2019) and Niskanen et al. (2017) reported on risk for major weight gain, defined as a 10% increase in body weight over 12–20 years, they found that risk increased by 52–313% for overweight and obese females at baseline who experienced high job demands. These odds for weight gain appear to be larger in size in contrast to studies that report the size of the association in BMI units (i.e., Fujishiro et al., 2015). However, Block et al. graphed the predictions of BMI at follow-up for the average values of the normal weight, overweight, and obese BMI categories at baseline. This showed that, when job demands were at the highest value, males and females with an average BMI in the obesity category at baseline had a BMI increase of approximately 3.5 BMI units above the average for normal-weight individuals. For overweight males and females, the interaction showed an increase of approximately 1.5 BMI units above the average. Further, Block et al. found that lower decision authority and skill discretion were associated with an increase of approximately 1.75 BMI units at follow-up in males whose BMI was higher at baseline relative to males who did not have a high BMI at baseline. To provide context for the size of the BMI increase estimated in Block et al., even a one-unit variation in BMI is considerable variation at a population health level (Brown et al., 2007; Franco et al., 2013). However, further research is needed to understand how baseline BMI may moderate an association between job strain with BMI over time, including estimating the size of an interaction.

It is likely that some of the inconsistency observed in findings, and the difficulty in drawing overall conclusions, is attributable to the small number of studies that have investigated the possible moderating role of baseline BMI, supporting the need for further research. Thus,

despite inconsistencies, there is some evidence that an association of job strain with BMI over time may depend on higher or lower baseline BMI, warranting further research.

5.3 Chapter Aims

As described above, only a small body of research has examined whether the association of job strain and BMI over time differs depending on baseline BMI. Only four studies have examined the possibility of an interaction using job strain explicitly, while other evidence has been reviewed from research using the components of job strain (high job demands and low job control). While the literature indicates some evidence that the association between job strain and BMI over time may differ by baseline BMI, the results are inconsistent, and this is the case for both males and females. It is likely that the small sample of studies from which to summarise evidence contributes to the inconsistency that is present. This gap in the literature forms the aims and focus for the analyses undertaken in the current chapter.

Building on the investigations of a main effect of job strain with BMI over time in the previous chapter, the analyses in the current chapter use the PATH data to investigate the key research question of whether an interaction of job strain with baseline BMI is associated with subsequent BMI over time. The analyses use the traditional categorical construction of job strain (as used by Fujishiro et al., 2015) to facilitate a comparison with the results of the previous longitudinal chapter. The analyses are stratified by sex following the evidence that patterns of interaction may differ for males and females.

The four longitudinal MLMs employed in the prior chapter are remodelled here, although baseline BMI (initial BMI at wave one) is removed from the dependent variable and instead entered as a predictor variable in interaction with job strain. Similar to the previous chapter, the examination of multiple data points over a substantial 12-year follow-up period builds on the existing literature, which has only used a maximum of two measurements of job strain and BMI

each, and has not accounted for individual-level variance because of the cross-sectional modelling techniques used (linear and logistic regressions).

5.4 Methods

5.4.1 Sample

The sample analysed in this chapter was the same as in Chapter 4, because the analyses in this chapter build upon and extend beyond the investigation in Chapter 4. The data analysed were collected from participants in the 40s cohort enrolled in the PATH Through Life survey, which sampled participants from the Canberra and Queanbeyan regions of Australia (ACT and NSW, respectively). The first four waves of data were used in the analyses, with data collected approximately every four years beginning in 2000, and with data collection for wave four of the 40s cohort beginning in 2012. Detailed information on participation rates per wave for the 40s cohort is available in Chapter 2. For the current analyses, the inclusion criteria were the same as those selected for Chapter 4, including that participants responded as being employed either full time or part time, and had information on the JDC scales. This resulted in 1,130 males and 1,141 females who met the criteria at wave one, 1,030 males and 1,076 females at wave two, 976 males and 1,021 females at wave three, and 700 males and 745 females at wave four. The multivariate samples differed slightly between the MLM analyses because not all participants had information on all relevant covariates and BMI from wave to wave.

5.4.2 Measures

5.4.2.1 *Job Strain*

Job strain and BMI at baseline (wave one) were the main independent variables of interest in these analyses, which aimed to investigate an association with BMI at waves two to four as the dependent variable. As a brief review, job strain was categorised similar to many previous studies; that is, median splits were used to categorise the job control and demands scales of the job strain measure. Where participants scored above the median on job demands

and below the median on job control, job strain was indicated (coded 1), and all other combinations were used as the reference category (coded 0).

5.4.2.2 BMI

BMI was calculated using participants' weight in kilograms divided by their height in metres squared (weight [kg]/height [m²]). Participants self-reported their weight at every wave to the nearest kilogram. Their height was self-reported only at waves one and two. Observations of BMI less than 18.5 (underweight) and greater than 50 at any wave were excluded from the analyses, although these participants were not permanently excluded from the analyses.

Baseline BMI was the only new independent variable to be included in the current chapter's models. In the previous chapter, BMI at wave one (baseline) was analysed within the dependent variable; however, here it was removed as a dependent variable and used as an independent predictor of BMI at the subsequent waves (two to four). Where it was modelled continuously, baseline BMI was zero-centred at the sex-specific mean of BMI at wave one (females: individual BMI at wave one: 25.81; males: individual BMI at wave one: 26.94). When modelled categorically, participants' BMI at wave one was coded 0 (normal weight), 1 (overweight), or 2 (obese), as per WHO BMI category cut-offs: 18.5–24.99 for normal weight, 25–29.99 for overweight, and >30 for obesity.

5.4.2.3 Covariates in Fully Adjusted Analyses

The included covariates were the same as in Chapters 3 and 4: having children, current smoking status, reported exercise intensity, presence of financial difficulty, physical and mental health, number of years of education completed, and job hours per week. More detailed information on job strain, BMI, and all covariates included in the analyses is available in Chapters 2 and 4. The covariate estimates reported throughout cannot be interpreted as total-effects estimates similar to the primary variable of interest, job strain (Westreich & Greenland, 2013; see Chapter 2 for a further explanation of the covariate estimates reported).

5.4.3 Statistical Models and Analyses

5.4.3.1 *Interaction of Job Strain and Baseline BMI*

The purpose of this chapter was to assess whether testing the interaction of job strain with baseline BMI may provide insights and clarity into the association between job strain and BMI over time, because prior research evidenced the possibility that an association may be moderated by higher or lower baseline BMIs. As such, the analytic structure of the longitudinal models in this chapter remained the same as in Chapter 4, and each of the four sets of longitudinal analysis models were repeated with the inclusion of a term representing the interaction of job strain with baseline BMI for all participants. The only modifications to the statistical models were the removal of wave one BMI from the dependent variable, which was instead used to create the interaction term with job strain that was tested in each model.

Following the previous chapter, the models are reported in the results as follows:

1. A general random effects model (with a random intercept) was conducted to evaluate evidence of an interaction of job strain with baseline BMI in association with BMI over time. Job strain information from all four waves interacted with baseline BMI was used to predict BMI from wave two, three and four.
2. A fixed effects model, omitting any time-invariant variables, was employed to test the interaction of baseline BMI with changes in job strain (an independent variable) in association with changes in BMI over the three waves (the dependent variable).
3. The baseline job strain model (a random effects model with a random intercept) was used to assess the interaction of baseline BMI with job strain reported at baseline only with BMI over the subsequent three waves.
4. A lagged model tested the interaction of baseline BMI and job strain at the prior wave (i.e., lagged) with BMI at subsequent waves, averaged over the available two lagged waves (the lagged association from job strain at wave one to BMI at wave two was the

reference lag, and the lagged effect was averaged over the lags from wave two to wave three, and from wave three to wave four).

5.4.3.2 Analyses with Continuous and Categorical BMI

The analyses were initially conducted with continuous baseline BMI interacted with job strain. Then, to provide further context for the interpretation of the results, each set of models was repeated using categorical baseline BMI interacted with job strain. To further investigate differences by baseline BMI, the four analytic models were also run stratified by baseline BMI category: normal weight, overweight and obese at baseline. In these models, only the main effect of job strain was tested for an association with BMI over waves two, three, and four (the exclusion of wave one BMI was maintained for consistency).

5.4.3.3 Models A and B: Restricted and Fully Adjusted Models

The four sets of MLMs were conducted twice. First, model A was a restricted model that included only job strain, baseline BMI, the interaction term, and the time indicator (wave) as independent variables. Subsequently, model B was additionally adjusted for all covariates. Except for education (a time-invariant variable assessed at wave two) and the main effect of baseline BMI, all covariates were time-varying across the four waves of data (not set at baseline). As in the previous chapters, to explore differences between sexes (as alluded to by the prior literature), the analyses were stratified by sex.

5.5 Results

5.5.1 Descriptive Statistics

Descriptive statistics for the sample at baseline are shown by sex and baseline BMI category in Tables 5.1 and 5.2. For males, proportions of job strain were highest among those who were obese at baseline and lowest among those with normal weight at baseline. The proportion of those with job strain was similar for females who were normal weight or obese at baseline, while those who were overweight at baseline had the smallest proportion of individuals

reporting job strain. However, these differences were not significant for either sex. Mean BMI for normal-weight females was lower than for males; however, the mean for overweight males and females was similar, and the mean BMI for obese females at baseline was higher than for males. The obese at baseline category had a standard deviation that was double the size of the normal and overweight at baseline categories, indicating greater variability in this group for both males and females. Proportions of children were similar for males and females across baseline BMI categories. Normal-weight males and overweight females at baseline reported the highest proportions of smoking, although these were not significantly different from the lowest proportions observed in obese males and normal-weight and obese females (whose proportions were similar). Hours and intensity of exercise engagement per week were significantly higher among those who were normal weight at baseline (for both sexes), with proportions predictably and significantly declining with overweight and obesity at baseline. Inversely, those who were obese at baseline had the highest proportions of low weekly exercise hours and intensity. Both obese males and females at baseline were the greatest proportions of those experiencing financial difficulty, although this difference was only significant among females.

Continuous variables at baseline were tested for differences between baseline BMI groups using ANOVA, and post hoc tests were conducted given a significant result. Mental health scores did not vary across baseline BMI categories for females and males. Physical health scores were highest for females who were normal weight at baseline and lowest for those who were obese at baseline, with contrasts showing that each group was significantly different from the others. There were no significant differences in the physical health scores of males who were normal weight and overweight at baseline, although those who were obese at baseline had significantly lower physical health from each of these groups. For females, mean years of education was highest for those who were normal weight at baseline, and post hoc tests showed a significant difference between the normal-weight group with both the overweight and obese

groups at baseline (but not between the overweight and obese groups at baseline) for females. While education was also highest among males who were normal weight at baseline, the obese at baseline group was the only group significantly different from the normal weight and overweight groups at baseline. Working hours per week were comparable across baseline BMI categories for both males and females.

Table 5.1*Descriptive Statistics at Baseline for Male Participants by Baseline BMI Category (at Wave 1)*

Baseline variable		Males			Sig.
		Normal weight	Overweight	Obese	
Categorical		N (%)			
Job strain	Yes	75 (19.74)	96 (20.38)	43 (22.75)	
	No	305 (80.26)	375 (79.62)	146 (77.25)	.697
Children	Yes	311 (81.84)	408 (86.62)	160 (84.66)	
	No	69 (18.16)	63 (13.38)	29 (15.34)	.159
Smoke	Yes	78 (20.53)	87 (18.47)	32 (16.93)	
	No	302 (79.47)	384 (81.53)	157 (83.07)	.552
Weekly exercise	Low	77 (20.98)	109 (24.72)	75 (41.44)	
	Moderate	148 (40.33)	182 (41.27)	65 (35.91)	
	High	142 (38.69)	150 (34.01)	41 (22.65)	.000
Finance probs	Yes	64 (20.45)	99 (24.57)	44 (27.33)	
	No	249 (79.55)	304 (75.43)	117 (72.67)	.204
Continuous		M (SD)			
BMI		23.13 (1.46)	27.27 (1.39)	32.97 (3.03)	.000
Mental health		50.27 (8.67)	50.49 (8.89)	50.22 (9.11)	.729
Physical health		52.52 (6.88)	52.24 (6.58)	50.05 (7.74)	.025
Education		15.05 (2.21)	14.96 (2.15)	14.47 (2.20)	.012
Work hours		46.29 (12.15)	47.94 (11.85)	48.04 (13.31)	.149
Total N		380	471	189	

Table 5.2*Descriptive Statistics at Baseline for Female Participants by Baseline BMI Category (at Wave 1)*

Baseline variable		Females			Sig.
		Normal weight	Overweight	Obese	
Categorical					
Job strain	Yes	147 (25.70)	56 (20.51)	51 (26.02)	.219
	No	425 (74.30)	217 (79.49)	145 (73.98)	
Children	Yes	503 (87.94)	245 (89.42)	171 (87.24)	.714
	No	69 (12.06)	28 (10.58)	25 (12.76)	
Smoke	Yes	94 (16.43)	55 (20.44)	33 (16.84)	.343
	No	478 (83.57)	218 (79.56)	163 (83.16)	
Weekly exercise	Low	191 (36.66)	125 (49.61)	108 (58.06)	.000
	Moderate	199 (38.20)	101 (39.76)	58 (31.18)	
	High	131 (25.14)	27 (10.63)	20 (10.75)	
Finance probs	Yes	96 (21.87)	38 (17.84)	49 (31.61)	.007
	No	343 (78.13)	175 (82.16)	106 (68.39)	
Continuous					
BMI		22.09 (1.70)	27.13 (1.30)	34.38 (3.92)	.000
Mental health		48.82 (9.32)	48.54 (9.40)	47.33 (9.26)	.152
Physical health		52.35 (7.12)	50.82 (7.80)	47.80 (8.88)	.000
Education		14.87 (2.14)	14.42 (2.24)	14.10 (2.05)	.000
Work hours		36.04 (13.96)	35.22 (13.68)	35.95 (13.84)	.717
Total N		572	273	196	

5.5.2 Sample Selection Per Analysis Model

Given the differences between the sets of models, the selection of participants for inclusion in each analysis differed slightly. Thus, across the four sets of analytic models analysing the full sample, the total number of participants included ranged from 973 males (2,315 total observations across four waves) in the random and fixed effects models to 944 males in the baseline job strain analyses (2,252 observations) and 945 (2,250 observations) in the lagged analyses. For females, the total number of participants included ranged from 1,043 females (2,347 observations) in the random and fixed effects analyses to 939 females (2,142 observations) in the baseline job strain analyses, and 984 (2,192 observations) in the lagged

analyses. Given these differences in numbers, the models were repeated with the same participants and data points included in all models. These additional sensitivity analyses showed the same pattern and significance; thus, it was concluded that the results were not attenuated by the differences in sample size selection, enabling comparisons between models A and B and across sets of models.

5.5.3 Interaction Between Baseline BMI and Job Strain and Stratified Analyses

5.5.3.1 Males

5.5.3.1.1 General random effects model (Table 5.3)

To estimate whether an association of job strain with BMI across three waves of data (waves two to four) was moderated by BMI at baseline, a random effects MLM (including an interaction term) was run. In analyses with the full sample (i.e., not stratified—both the analysis with baseline BMI entered continuously [top panel in table] and by baseline BMI category [second panel in table]), no evidence was found of an association of job strain with BMI, or an interaction of job strain with baseline BMI. Further, when the main effect of job strain on BMI over time was tested with the sample stratified by baseline BMI (last three panels in the table), no evidence was observed for an association of job strain with BMI over time in those of normal weight, overweight, or obese at wave one. This result held for males across both models A and B.

Table 5.3

Males' BMI Over Time as a Function of the Interaction Between Job Strain and Baseline BMI: General Random Effects Model

Random effects			Model A				Model B			
Full sample, continuous BMI	Male		B	P	CI95		B	P	CI95	
	Job strain	No	Reference				Reference			
		Yes	−0.018	0.867	−0.233	0.197	−0.053	0.628	−0.266	0.161
	Baseline BMI		0.697	0.000	0.661	0.733	0.685	0.000	0.649	0.721
	Baseline BMI*Job strain		−0.014	0.574	−0.062	0.034	−0.010	0.694	−0.057	0.038
	Wave (2)	3	0.375	0.000	0.251	0.498	0.359	0.000	0.236	0.481
		4	0.592	0.000	0.448	0.736	0.559	0.000	0.414	0.705
	Obs, N		2,315, 973				2,315, 973			
Full sample, categorical BMI			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.018	0.925	−0.389	0.354	−0.043	0.820	−0.410	0.325
	Baseline BMI cat.	Normal	Reference				Reference			
		Overweight	3.873	0.000	3.538	4.208	3.834	0.000	3.502	4.167
		Obesity	8.921	0.000	8.490	9.351	8.753	0.000	8.322	9.184
	Baseline cat*Job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	−0.016	0.947	−0.495	0.463	−0.057	0.813	−0.530	0.416
		Strain*Obesity	−0.009	0.977	−0.647	0.628	0.040	0.902	−0.590	0.669
	Wave	3	0.361	0.000	0.238	0.485	0.343	0.000	0.221	0.466
		4	0.574	0.000	0.430	0.718	0.536	0.000	0.390	0.681
	Obs, N		2,315, 973				2,315, 973			
Normal weight at baseline			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.027	0.859	−0.319	0.266	−0.048	0.750	−0.340	0.245
	Wave (2)	3	0.310	0.000	0.140	0.462	0.310	0.000	0.149	0.471
		4	0.540	0.000	0.349	0.731	0.553	0.000	0.360	0.745
	Obs, N		834, 357				834, 357			
Overweight at baseline			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.041	0.778	−0.330	0.247	−0.081	0.578	−0.365	0.204

	Wave (2)	3	0.348	0.000	0.172	0.523	0.322	0.000	0.149	0.494
		4	0.507	0.000	0.305	0.709	0.438	0.000	0.235	0.641
	Obs, N		1,062, 436				1,062, 436			
Obese at baseline	Job strain	No	Reference				Reference			
		Yes	−0.045	0.904	−0.773	0.683	0.017	0.964	−0.724	0.758
	Wave (2)	3	0.526	0.011	0.120	0.932	0.450	0.034	0.035	0.865
		4	0.835	0.001	0.357	1.313	0.721	0.004	0.234	1.208
	Obs, N		419, 180				419, 180			

5.5.3.1.2 Baseline Job Strain Models (Table 5.4)

To test specifically whether the risk of baseline job strain on later BMI is moderated by initial (baseline) BMI, a random effects MLM was run. In the models where baseline BMI was interacted continuously with job strain at baseline, the interaction terms in both model A and model B reached statistical significance ($B = -.259$, $p < .001$, model B, graphically represented in Figure 5.1) across the full sample of males. However, the full sample analyses using categorical baseline BMI interacted with job strain, and the analyses stratified by baseline BMI category, showed no evidence for an interaction.

5.5.3.1.3 Fixed Effects Models (Table 5.5)

The fixed effects models did not show any evidence that changes in job strain interacted with baseline BMI were associated with changes in BMI across the study period. This held when baseline BMI was modelled both continuously and categorically. The analyses stratified by baseline BMI category also showed no evidence for an association within each baseline category group.

5.5.3.1.4 Lagged Effects Models (Table 5.6)

With the full sample of male participants, in analyses with baseline BMI modelled both categorically and continuously, the lagged effects models demonstrated no evidence for an interaction between lagged job strain and baseline BMI. Additionally, no evidence of differences based on baseline BMI category was found in the stratified analyses.

Table 5.4

Males' BMI Over Time as a Function of the Interaction Between Job Strain at Baseline and Baseline BMI: Random Effects Model

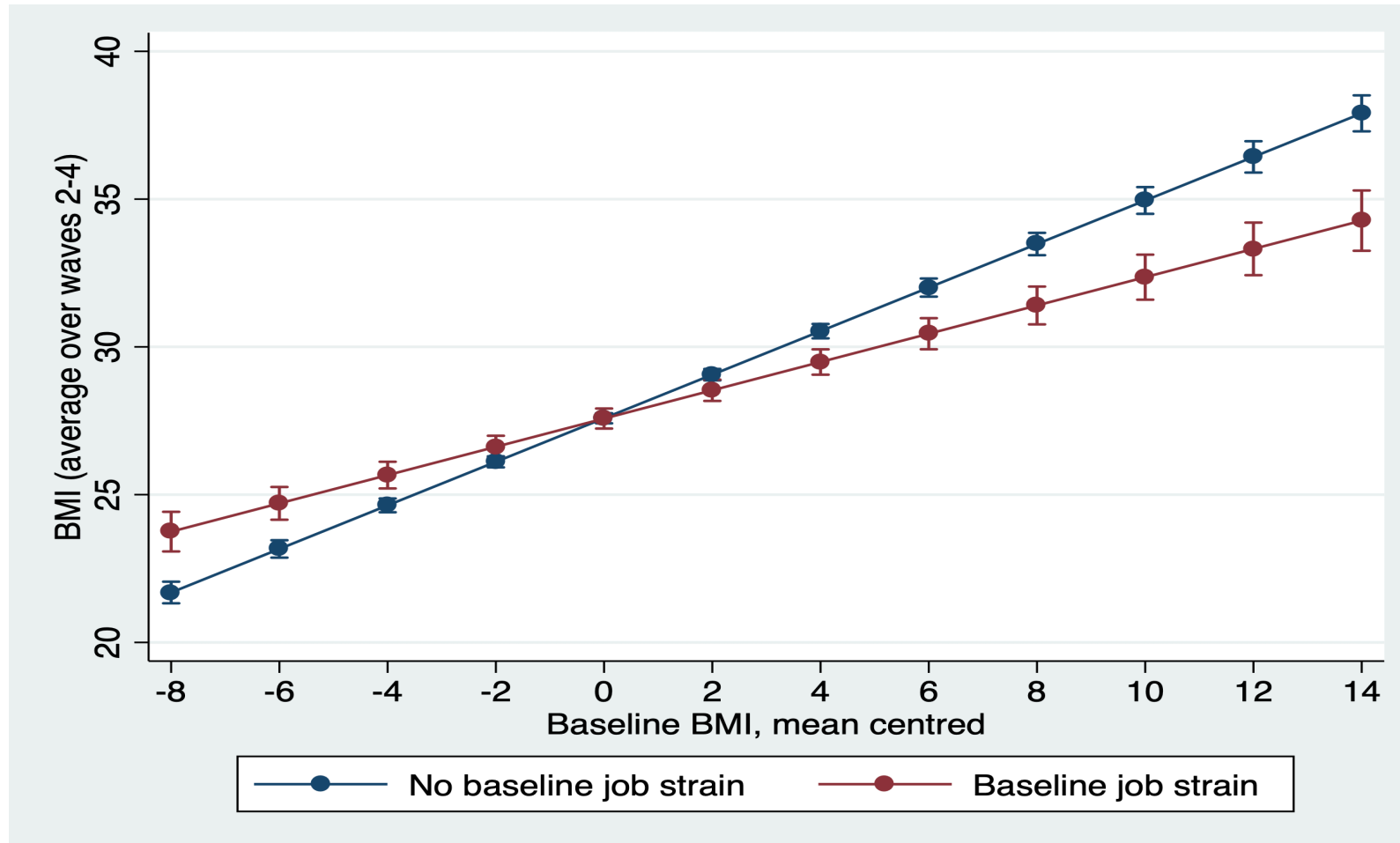
B. job strain random effects			Model A				Model B			
Full sample, continuous BMI	Male		B	P	CI95		B	P	CI95	
	B. job strain	No	Reference				Reference			
		Yes	0.035	0.859	-0.350	0.419	-0.010	0.960	-0.391	0.371
	Baseline BMI		0.747	0.000	0.706	0.789	0.737	0.000	0.696	0.778
	Baseline*Job BMI									
	*B. job strain		-0.251	0.000	-0.334	-0.169	-0.259	0.000	-0.340	-0.178
	Wave (2)	3	0.369	0.000	0.245	0.493	0.353	0.000	0.229	0.476
		4	0.559	0.000	0.414	0.704	0.530	0.000	0.384	0.677
	Obs, N		2,252, 944				2,252, 944			
Full sample, categorical BMI	B. job strain	No	Reference							
		Yes	0.241	0.442	-0.373	0.854	0.219	0.481	-0.390	0.827
	Baseline BMI category	Normal weight	Reference				Reference			
		Overweight	3.856	0.000	3.492	4.221	3.818	0.000	3.457	4.179
		Obesity	8.935	0.000	8.458	9.413	8.784	0.000	8.308	9.260
	Baseline cat*B. job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	-0.019	0.963	-0.836	0.797	-0.064	0.876	-0.873	0.745
		Strain*Obesity	-0.699	0.183	-1.727	0.329	-0.732	0.159	-1.751	0.287
	Wave	3	0.355	0.000	0.231	0.479	0.336	0.000	0.213	0.460
		4	0.545	0.000	0.400	0.690	0.511	0.000	0.364	0.657
Normal weight	Obs, N		2,252, 944				2,252, 944			
	B. job strain	No	Reference				Reference			
		Yes	0.240	0.356	-0.270	0.751	0.205	0.429	-0.303	0.712
	Wave (2)	3	0.318	0.000	0.157	0.479	0.322	0.000	0.161	0.484
		4	0.548	0.000	0.356	0.739	0.563	0.000	0.369	0.757
Overweight	Obs, N		808, 345				808, 345			
	B. job strain	No	Reference				Reference			

		0.218	0.386	-0.274	0.710	0.158	0.531	-0.337	0.654	0.654
	Wave (2)	0.335	0.000	0.158	0.512	0.311	0.000	0.137	0.485	0.485
		0.479	0.000	0.275	0.684	0.418	0.000	0.212	0.624	0.624
	Obs, N					1045,				
		1044, 428				428				
Obese	B. job strain	No	Reference				Reference			
		-0.452	0.453	-1.631	0.728	-0.581	0.320	-1.725	0.563	0.563
	Wave (2)	0.490	0.020	0.078	0.901	0.405	0.060	-0.016	0.826	0.826
		0.733	0.003	0.250	1.217	0.609	0.015	0.117	1.101	1.101
	Obs, N	400,				400,				
		171				171				

Notes. B. job strain = baseline job strain. Specific to effects for job strain: Bold indicates $p < .05$.

Figure 5.1

Interaction Between Job Strain at Baseline and Males' Baseline BMI Predicting BMI Over Time



Notes. Baseline BMI centred (zero) at 26.94. Estimates graphed are from model B with 95% confidence intervals shown around the estimates.

Table 5.5

Males' Change in BMI as a Function of the Interaction Between Change in Job Strain and Baseline BMI: Fixed Effects Model

Fixed effects			Model A				Model B			
Full sample, continuous BMI	Male		B	P	CI95		B	P	CI95	
	Job strain	No	Reference				Reference			
		Yes	−0.041	0.732	−0.276	0.194	−0.052	0.664	−0.285	0.182
	Baseline BMI		(omitted)				(omitted)			
	Baseline BMI*Job strain		−0.004	0.867	−0.057	0.048	−0.001	0.956	−0.053	0.050
	Wave (2)	3	0.374	0.000	0.249	0.499	0.353	0.000	0.228	0.478
		4	0.604	0.000	0.457	0.750	0.547	0.000	0.398	0.696
	Obs, N		2,315, 973				2,315, 973			
Full sample, categorical BMI			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.082	0.693	−0.489	0.325	−0.097	0.638	−0.499	0.306
	Baseline BMI category	Normal weight	Reference				Reference			
		Overweight	(omitted)				(omitted)			
		Obesity	(omitted)				(omitted)			
	Baseline cat*Job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	0.079	0.767	−0.446	0.604	0.053	0.842	−0.466	0.571
		Strain*Obesity	0.002	0.995	−0.707	0.711	0.111	0.755	−0.590	0.813
	Wave	3	0.373	0.000	0.248	0.498	0.352	0.000	0.227	0.477
		4	0.603	0.000	0.456	0.750	0.546	0.000	0.397	0.695
	Obs, N		2,315, 973				2,315, 973			
Normal weight			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.085	0.600	−0.405	0.234	−0.107	0.512	−0.429	0.214
	Wave (2)	3	0.302	0.000	0.139	0.466	0.304	0.000	0.137	0.470
		4	0.574	0.000	0.379	0.769	0.559	0.000	0.359	0.760
	Obs, N		834, 357				834, 357			
Overweight			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.007	0.968	−0.328	0.315	−0.052	0.750	−0.369	0.266

	Wave (2)	3	0.349	0.000	0.171	0.527	0.322	0.000	0.146	0.498
		4	0.511	0.000	0.305	0.716	0.447	0.000	0.238	0.656
	Obs, N		1,062, 436				1,062, 436			
Obese	Job strain	No	Reference				Reference			
		Yes	−0.104	0.802	−0.917	0.710	0.082	0.848	−0.757	0.921
	Wave (2)	3	0.582	0.006	0.167	0.997	0.522	0.017	0.094	0.950
		4	0.910	0.000	0.421	1.398	0.796	0.002	0.290	1.303
	Obs, N		419, 180				419, 180			

Table 5.6

Males' BMI Over Time as a Function of the Interaction Between Job Strain at a Prior Wave and Baseline BMI: Lagged Effects Model

Lagged job strain, random effects			Model A				Model B			
Full sample, continuous BMI	Male		B	P	CI95		B	P	CI95	
	L. job strain	No	Reference				Reference			
		Yes	0.053	0.601	−0.145	0.251	0.066	0.510	−0.130	0.262
	Baseline BMI		0.690	0.000	0.654	0.727	0.678	0.000	0.642	0.715
	Baseline BMI *L. job strain		0.014	0.547	−0.030	0.057	0.009	0.700	−0.035	0.052
	Wave (2)	3	0.368	0.000	0.243	0.492	0.355	0.000	0.230	0.479
		4	0.563	0.000	0.417	0.709	0.540	0.000	0.393	0.688
	Obs, N		2,250, 945				2,250, 945			
Full sample, categorical BMI			Reference				Reference			
	L. job strain	No	Reference				Reference			
		Yes	0.004	0.979	−0.326	0.335	0.010	0.954	−0.318	0.337
	Baseline BMI cat	Normal weight	Reference				Reference			
		Overweight	3.861	0.000	3.522	4.201	3.810	0.000	3.472	4.147
		Obesity	8.946	0.000	8.506	9.387	8.785	0.000	8.343	9.226
	Baseline cat*L. job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	0.025	0.911	−0.409	0.458	0.044	0.840	−0.384	0.472
		Strain*Obesity	0.142	0.637	−0.448	0.733	0.130	0.664	−0.454	0.714
	Wave	3	0.361	0.000	0.236	0.486	0.347	0.000	0.223	0.472
		4	0.545	0.000	0.399	0.692	0.517	0.000	0.369	0.664
	Obs, N		2,250, 945				2,250, 945			
Normal weight			Reference				Reference			
	L. job strain	No	Reference				Reference			
		Yes	−0.007	0.961	−0.268	0.255	−0.001	0.996	−0.261	0.260
	Wave (2)	3	0.318	0.000	0.155	0.480	0.327	0.000	0.165	0.490
		4	0.544	0.000	0.350	0.737	0.564	0.000	0.368	0.759
	Obs, N		812, 348				812, 348			
Overweight			Reference				Reference			
	L. job strain	No	Reference				Reference			

		Yes	0.024	0.861	−0.246	0.294	0.040	0.771	−0.226	0.305
	Wave (2)	3	0.328	0.000	0.151	0.504	0.307	0.001	0.133	0.482
		4	0.460	0.000	0.254	0.665	0.404	0.000	0.197	0.611
	Obs, N		1,037, 426				1,037, 426			
Obese	L. job strain	No	Reference				Reference			
		Yes	0.229	0.521	−0.470	0.927	0.189	0.593	−0.504	0.881
	Wave (2)	3	0.550	0.010	0.131	0.969	0.466	0.033	0.039	0.893
		4	0.800	0.001	0.311	1.289	0.698	0.006	0.202	1.194
	Obs, N		401, 171				401, 171			

Notes. L. job strain = lagged job strain.

5.5.3.2 Females

5.5.3.2.1 General Random Effects Models (Table 5.7)

The first general random effects MLM tested an overall association between job strain and BMI across the waves of data. In the analyses with the full sample of females with baseline BMI entered continuously, the interaction term between baseline BMI and job strain approached significance in model A ($p=.057$, $B=.050$), with a slight reduction in statistical significance when adjusted with covariates in model B ($p=.035$, $B=.054$). However, further analysis modelling baseline BMI categorically did not support any a priori statistical evidence for an interaction between job strain and baseline BMI category.

The random effects model was repeated after stratifying the sample by baseline BMI category, although no evidence was found that job strain was related to BMI outcomes across the study in any baseline BMI category.

5.5.3.2.2 Baseline Job Strain Models (Table 5.8)

With baseline BMI modelled continuously, analysis of the full sample of females showed a statistically significant interaction between baseline BMI and baseline job strain with subsequent BMI across the study period that held across both models A and B ($B=0.151$, $p<.001$, model B, graphically presented in Figure 5.2). However, further analyses modelling BMI categorically in the full sample of females, and the analyses separated by baseline BMI category, did not provide any confirmatory evidence for the existence of differences in BMI associated with job strain based on BMI baseline category.

Table 5.7

Females' BMI Over Time as a Function of the Interaction Between Job Strain and Baseline BMI: Random Effects Model

Random effects			Model A				Model B			
Full sample, continuous BMI	Female		B	P	CI95		B	P	CI95	
	Job strain	No	Reference				Reference			
		Yes	0.021	0.864	−0.218	0.260	0.002	0.984	−0.233	0.238
	Baseline BMI		0.826	0.000	0.793	0.860	0.799	0.000	0.766	0.833
	Baseline BMI*Job strain		0.050	0.057	−0.002	0.102	0.055	0.035	0.004	0.106
	Wave (2)	3	0.696	0.000	0.538	0.854	0.609	0.000	0.451	0.766
		4	1.176	0.000	0.989	1.362	1.062	0.000	0.874	1.251
	Obs, N		2,347, 1,043				2,347, 1,043			
Full sample, categorical BMI	Job strain	No	Reference				Reference			
		Yes	0.106	0.531	−0.226	0.438	0.054	0.747	−0.273	0.380
	Baseline BMI cat	Normal								
		Overweight	4.908	0.000	4.444	5.373	4.737	0.000	4.280	5.194
		Obesity	11.352	0.000	10.829	11.874	10.956	0.000	10.437	11.47
										6
	Baseline cat*Job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	−0.400	0.160	−0.957	0.157	−0.308	0.269	−0.854	0.239
		Strain*Obesity	−0.008	0.982	−0.679	0.664	0.062	0.854	−0.597	0.721
	Wave	3	0.704	0.000	0.545	0.863	0.613	0.000	0.455	0.772
		4	1.165	0.000	0.977	1.353	1.045	0.000	0.855	1.234
	Obs, N		2,347, 1,043				2,347, 1,043			
Normal weight at baseline	Job strain	No	Reference				Reference			
		Yes	0.122	0.375	−0.148	0.392	0.109	0.425	−0.159	0.378
	Wave (2)	3	0.721	0.000	0.547	0.896	0.658	0.000	0.481	0.835
		4	0.994	0.786	0.349	1.201	0.917	0.000	0.706	1.127
	Obs, N		1,299, 572				834, 357			
	Job strain	No	Reference				Reference			

Overweight at baseline		Yes	−0.041	0.778	−0.330	0.247	−0.081	0.578	−0.365	0.204
	Wave (2)	3	0.348	0.000	0.172	0.523	0.322	0.000	0.149	0.494
		4	0.507	0.000	0.305	0.709	0.438	0.000	0.235	0.641
	Obs, N		1,299, 572				1,299, 572			
Obese at baseline	Job strain	No	Reference				Reference			
		Yes	−0.298	0.203	−0.757	0.161	−0.264	0.250	−0.713	0.186
	Wave (2)	3	0.755	0.000	0.426	1.083	0.688	0.000	0.363	1.014
		4	1.252	0.000	0.874	1.631	1.120	0.000	0.735	1.504
	Obs, N		608, 273				608, 273			

Notes. Specific to effects for job strain: Bold indicates $p < .05$.

Table 5.8

Females' BMI Over Time as a Function of the Interaction Between Job Strain at Baseline and Baseline BMI: Random Effects Model

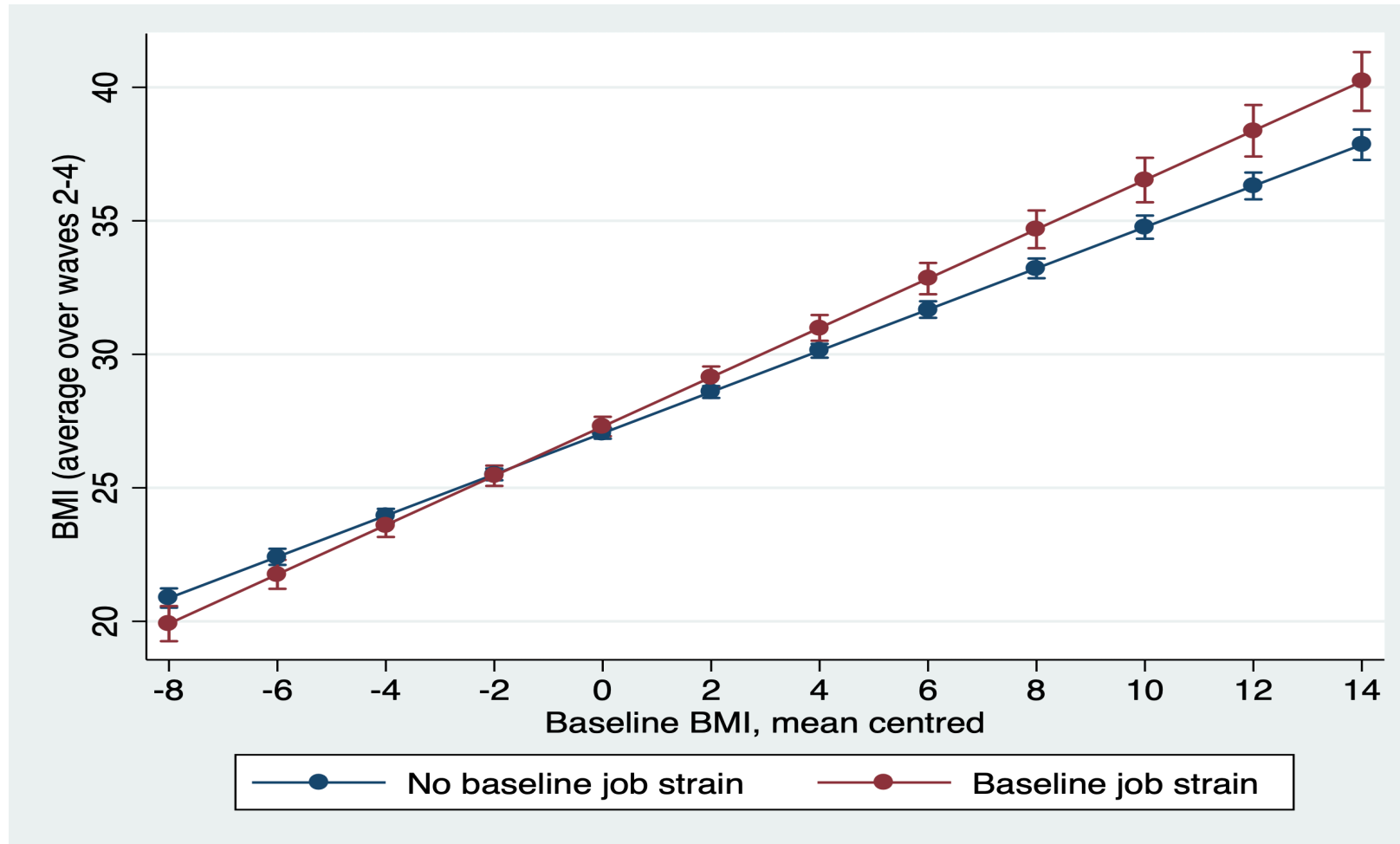
Baseline job strain random effects			Model A				Model B			
Full sample, continuous BMI	Female B. job strain	No Yes	B Reference	P	CI95		B Reference	P	CI95	
	Baseline BMI		0.795	0.000	0.757	0.833	0.772	0.000	0.734	0.809
	Baseline BMI*B. job strain		0.155	0.000	0.073	0.238	0.151	0.000	0.070	0.232
	Wave (2)	3	0.704	0.000	0.541	0.868	0.623	0.000	0.461	0.786
		4	1.129	0.000	0.935	1.323	1.022	0.000	0.826	1.218
	Obs, N		2,142, 939				2,142, 939			
Full sample, categorical BMI	B. job strain	No Yes	Reference				Reference			
	Baseline BMI category	Normal weight Overweight Obesity	0.357 Reference 4.982 11.516	0.246 0.000 0.000	−0.247 4.444 10.906	0.961 5.520 12.126	0.283 Reference 4.821 11.151	0.350 0.000 0.000	−0.310 4.292 10.547	0.876 5.351 11.756
	Baseline cat*B. job strain	No strain*Normal Strain*Overweight Strain*Obesity	Reference −0.454 −0.464	0.433 0.445	−1.589 −1.657	0.681 0.728	Reference −0.446 −0.458	0.433 0.443	−1.561 −1.628	0.669 0.712
	Wave	3 4	0.717 1.123	0.000 0.000	0.553 0.928	0.882 1.319	0.637 1.016	0.000 0.000	0.474 0.818	0.801 1.213
	Obs, N		2,142, 939				2,142, 939			
Normal weight	B. job strain	No Yes	Reference				Reference			
	Wave (2)	3 4	0.730 0.957	0.000 0.000	0.550 0.742	0.910 1.172	0.664 0.880	0.000 0.000	0.482 0.661	0.846 1.098
	Obs, N		1,203, 521				1,203, 521			
Overweight	B. job strain	No	Reference				Reference			

		Yes	-0.120	0.785	-0.980	0.741	-0.158	0.718	-1.014	0.698
	Wave (2)	3	0.751	0.000	0.401	1.101	0.717	0.000	0.370	1.064
		4	1.257	0.000	0.851	1.663	1.150	0.000	0.731	1.568
	Obs, N		535, 239				535, 239			
Obese	B. job strain	No	Reference				Reference			
		Yes	-0.107	0.896	-1.714	1.499	-0.305	0.704	-1.874	1.265
	Wave (2)	3	0.663	0.010	0.159	1.167	0.562	0.019	0.092	1.032
		4	1.495	0.000	0.889	2.100	1.229	0.000	0.652	1.805
	Obs, N		404, 179				404, 179			

Notes. B. job strain = baseline job strain. Specific to effects for job strain: Bold indicates $p < .05$.

Figure 5.2

Interaction Between Job Strain at Baseline and Females' Baseline BMI Predicting BMI Over Time



Notes. Baseline BMI centred (0) at 25.81. Estimates graphed are from model B with 95% confidence intervals shown around the estimates.

5.5.3.2.3 Fixed Effects Models (Table 5.9)

As with males, the fixed effects analysis models analysing data from females did not show any evidence for an interaction between baseline BMI and change in job strain in association with change in BMI over the study. This was observed with both continuous and categorical BMI interacted with job strain, and no further evidence was found when the analyses were repeated within baseline BMI categories.

5.5.3.2.4 Lagged Effects Models (Table 5.10)

The interaction of baseline BMI with lagged job strain (i.e., four years earlier than the measure of BMI at a later wave) was statistically significant in the full sample analyses with baseline BMI modelled continuously (in both models A and B) ($B=0.085$, $p=.001$, model B which is graphically represented in Figure 5.3). Additional to the significance of the interaction term, the main effect of lagged job strain was significant in model A ($B=.255$, $p=.034$) and was not meaningfully attenuated after adjustment for covariates in model B ($B=.250$, $p=.034$). When baseline BMI was modelled categorically using the full sample of females, there was no evidence for a main effect of lagged job strain, but the interaction between job strain and baseline obesity in model A approached significance at the .05 alpha level ($B=.617$, $p=.058$). However, in model B, the interaction between baseline obesity and job strain was attenuated ($B=.500$, $p=.118$).

When the analyses were stratified by baseline BMI category, no significant main effects were apparent for females who were normal weight, overweight, or obese at baseline.

Table 5.9

Females' Change in BMI as a Function of the Interaction Between Change in Job Strain and Baseline BMI: Fixed Effects

Fixed effects			Model A				Model B			
Full sample, continuous BMI	Female		B	P	CI95		B	P	CI95	
	Job strain	No	Reference				Reference			
		Yes	−0.045	0.738	−0.312	0.221	0.000	0.999	−0.263	0.263
	Baseline BMI		(omitted)				(omitted)			
	Baseline BMI*Job strain		0.005	0.874	−0.055	0.065	0.009	0.761	−0.050	0.068
	Wave (2)	3	0.697	0.000	0.536	0.858	0.614	0.000	0.452	0.775
		4	1.186	0.000	0.995	1.378	1.061	0.000	0.866	1.255
	Obs, N		2,347, 1,043				2,347, 1,043			
Full sample, categorical BMI			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.001	0.995	−0.369	0.366	0.007	0.968	−0.354	0.369
	Baseline BMI category	Normal weight	Reference				Reference			
		Overweight	(omitted)				(omitted)			
		Obesity	(omitted)				(omitted)			
	Baseline cat*Job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	−0.274	0.373	−0.878	0.330	−0.181	0.549	−0.774	0.412
		Strain*Obesity	0.228	0.548	−0.517	0.972	0.268	0.473	−0.464	1.000
	Wave	3	0.697	0.000	0.536	0.859	0.615	0.000	0.453	0.776
		4	1.182	0.000	0.991	1.373	1.058	0.000	0.864	1.253
	Obs, N		2,347, 1,043				2,347, 1,043			
Normal weight			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	0.007	0.962	−0.295	0.310	0.034	0.823	−0.268	0.337
	Wave (2)	3	0.715	0.000	0.538	0.893	0.674	0.000	0.493	0.856
		4	0.994	0.000	0.782	1.206	0.919	0.000	0.703	1.136
	Obs, N		1,209, 572				1,209, 572			
Overweight			Reference				Reference			
	Job strain	No	Reference				Reference			
		Yes	−0.271	0.291	−0.775	0.233	−0.138	0.587	−0.635	0.360

	Wave (2)	3	0.699	0.000	0.362	1.035	0.621	0.000	0.283	0.960
		4	1.230	0.000	0.841	1.619	1.091	0.000	0.685	1.498
	Obs, N		608, 273				608, 273			
Obese	Job strain	No	Reference				Reference			
		Yes	0.189	0.673	−0.691	1.068	0.490	0.253	−0.352	1.331
	Wave (2)	3	0.627	0.014	0.128	1.127	0.459	0.059	−0.017	0.935
		4	1.698	0.000	1.091	2.306	1.409	0.000	0.818	1.999
	Obs, N		440, 198				440, 198			

Table 5.10

Females' BMI Over Time as a Function of the Interaction Between Job Strain at a Prior Wave and Baseline BMI: Lagged Effects Model

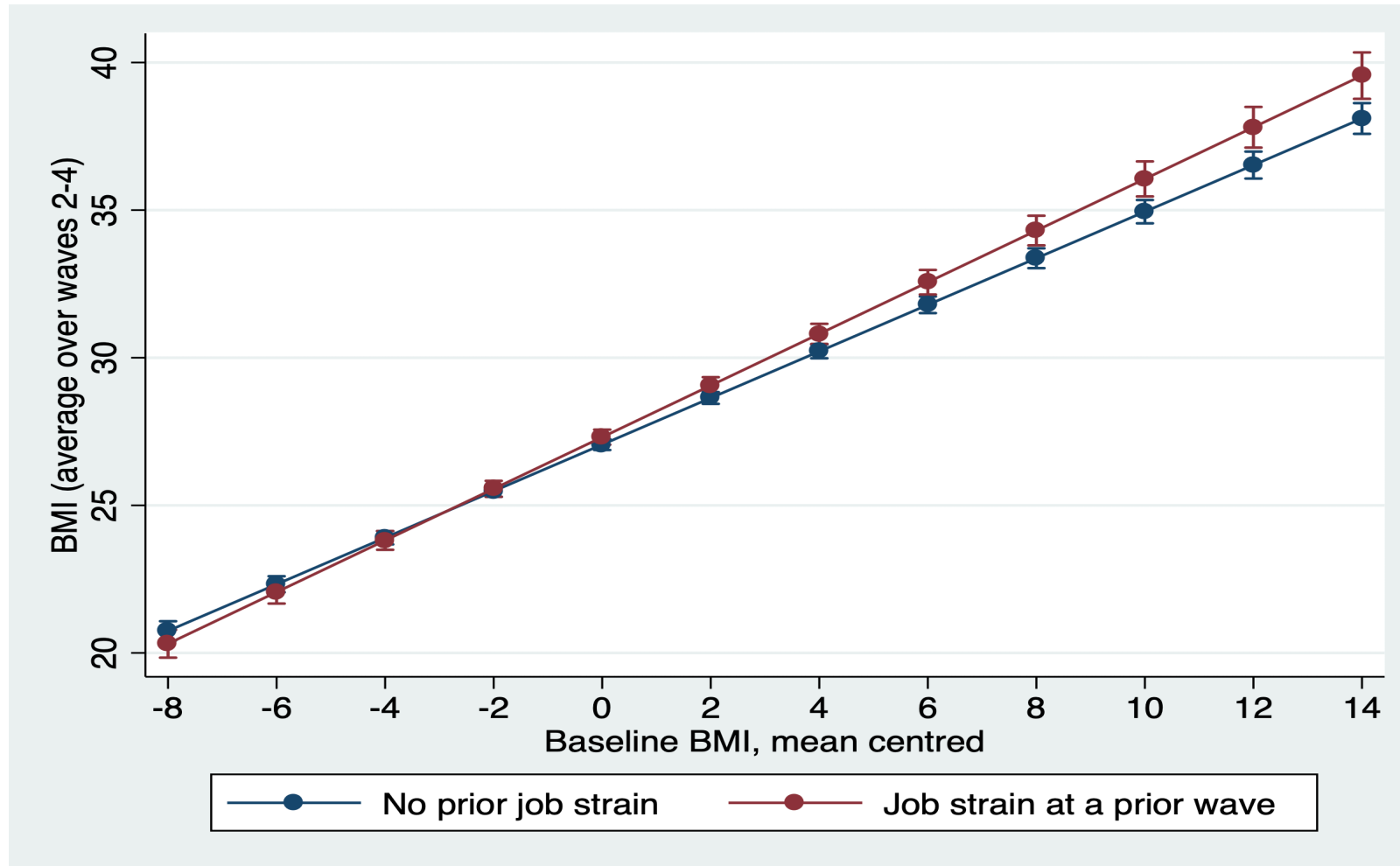
Lagged job strain, random effects			Model A				Model B			
Full sample, continuous BMI	Female		B	P	CI95		B	P	CI95	
	L. job strain	No	Reference				Reference			
		Yes	0.255	0.034	0.019	0.491	0.251	0.034	0.019	0.482
	Baseline BMI		0.815	0.000	0.780	0.849	0.789	0.000	0.755	0.823
	Baseline BMI*L. job strain		0.088	0.001	0.038	0.138	0.086	0.001	0.037	0.135
	Wave (2)	3	0.706	0.000	0.542	0.870	0.620	0.000	0.456	0.783
		4	1.222	0.000	1.027	1.417	1.108	0.000	0.911	1.305
	Obs, N		2,192, 984				2,192, 984			
Full sample, categorical BMI			Reference				Reference			
	L. job strain	No	Reference				Reference			
		Yes	0.044	0.786	−0.277	0.366	0.057	0.721	−0.258	0.373
	Baseline BMI cat	Normal weight	Reference				Reference			
		Overweight	4.832	0.000	4.349	5.316	4.664	0.000	4.188	5.140
		Obesity	11.252	0.000	10.712	11.792	10.897	0.000	10.361	11.432
	Baseline cat*L. job strain	No strain*Normal	Reference				Reference			
		Strain*Overweight	0.148	0.606	−0.415	0.711	0.189	0.504	−0.365	0.742
		Strain*Obesity	0.617	0.058	−0.021	1.255	0.500	0.118	−0.126	1.126
	Wave	3	0.721	0.000	0.555	0.886	0.632	0.000	0.466	0.797
		4	1.227	0.000	1.030	1.424	1.106	0.000	0.907	1.305
	Obs, N		2,192, 984				2,192, 984			
Normal weight			Reference				Reference			
	L. job strain	No	Reference				Reference			
		Yes	0.041	0.761	−0.221	0.302	0.067	0.612	−0.192	0.326
	Wave (2)	3	0.727	0.000	0.546	0.907	0.663	0.000	0.481	0.846
		4	1.016	0.000	0.801	1.230	0.936	0.000	0.719	1.154
	Obs, N		1,221, 536				1,221, 536			
Overweight			Reference				Reference			
	L. job strain	No	Reference				Reference			
		Yes	0.157	0.514	−0.314	0.628	0.146	0.536	−0.316	0.608

	Wave (2)	3	0.749	0.000	0.405	1.094	0.692	0.000	0.351	1.034
		4	1.379	0.000	0.974	1.784	1.260	0.000	0.847	1.673
	Obs, N		553, 257				553, 257			
Obese	L. job strain	No	Reference				Reference			
		Yes	0.666	0.090	−0.105	1.437	0.408	0.270	−0.317	1.132
	Wave (2)	3	0.683	0.009	0.168	1.198	0.511	0.039	0.025	0.996
		4	1.707	0.000	1.087	2.327	1.360	0.000	0.763	1.956
	Obs, N		418, 191				418, 191			

Notes. L. job strain = lagged job strain. Specific to effects for job strain: Bold indicates $p < .05$.

Figure 5.3

Interaction Between Experiencing Job Strain at an Earlier Wave and Females' BMI at Baseline Predicting BMI Over Time



Notes. Baseline BMI centred (0) at 25.81. Estimates graphed are from model B with 95% confidence intervals shown around the estimates.

5.6 Discussion

The aim of the current chapter was to investigate whether an association between job strain and BMI over time might depend on baseline BMI. Overall, the results show minimal consistent evidence that a status of higher or lower BMI at baseline goes on to either compound or ameliorate an association that job strain might have with BMI over time. Across four different types of analytic models (general random effects, baseline job strain, fixed effects, and lagged job strain), the most consistent finding was the lack of evidence for an interaction of job strain with baseline BMI. While there were occasional statistically significant findings (in particular, some trends for females that are discussed below), these were rarely replicated when interactions were tested using both a continuous and a categorical measure of baseline BMI, and they were not consistently observable when the main effects of job strain were tested and compared within baseline BMI categories.

The lack of robust evidence that baseline BMI is influential in the current findings is somewhat inconsistent with the small amount of existing literature that has similarly examined the question of whether job strain interacts with baseline BMI to affect later BMI. As reviewed in the introduction of this chapter, there is support (while acknowledging there are inconsistencies and important limitations) that both males and females with higher BMIs at baseline will, given an experience of job strain, experience greater BMI increases than those with more average BMIs. This is noted with the exception of the null findings reported by Ishizaki et al. (2008), making the findings from this chapter's analyses not entirely unprecedented.

5.6.1 Findings for Males

For males, the consistency of the null findings across each of the analytic models was such that there was only one instance of statistical significance for the full sample—namely, the interaction between job strain at baseline and baseline BMI. A visual inspection (see

Figure 5.1) generally showed the same pattern and no substantive differences. This is somewhat at odds with the few prior studies examining the interaction between job strain and baseline BMI on BMI over time for males. For example, Kivimäki et al. (2006) found that job strain was associated with increased BMI over time in males whose BMI was higher at baseline. Additionally, they found that components of job strain (low job control) interact with baseline BMI. Block et al. (2009) reported that the components of job strain (low skill discretion and decision authority [i.e., job control] and high job demands) were associated with increased weight gain among those whose baseline BMI was higher. Niskanen et al. (2017) also reported a significant interaction of job strain with baseline BMI for males. However, in contrast to the results of others, this finding was of a greater BMI increase among males who were normal weight at baseline. While the current chapter's results for males are largely inconsistent with those of prior studies, differences in how the studies were conducted make comparisons difficult. None of the prior studies examined more than two measurements of BMI (or body weight), whereas three measurements of BMI over time were analysed in this chapter (as the dependent variable) and, as previously mentioned, both job strain and BMI measures have been operationalised differently across studies.

While further research is required to demonstrate replicability, the results presented in this chapter's analyses are comprehensive and consistent. They show that, for males, there is no relationship between job strain and BMI over time (general random effects model), there is no relationship between changes in job strain with changes in BMI over eight years (fixed effects model), there is no relationship between job strain at baseline and BMI over the subsequent eight years (baseline job strain model), and there is no averaged relationship between job strain and BMI four years later (lagged effects model). Further, BMI at baseline does not moderate an association of job strain and BMI over time.

5.6.2 Findings for Females

The results for females in this chapter's analyses also indicate minimal evidence overall that baseline BMI moderates an association of job strain with BMI over time across all models. While some statistically significant interactions were reported in the general random effects and baseline job strain models using continuous baseline BMI, these were not supported in further analyses using categorical baseline BMI in the interaction term, or in the stratified analyses. Further, the results of the fixed effects analyses are consistent in their null findings for females. Thus, in summary, no robust evidence was found or substantiated to support the influence of baseline BMI across these models. To some extent, the inconsistent results demonstrate the value in modelling the relationship in various ways simultaneously (where it is known that the sample has not changed and other confounds are held constant between the models), because this highlights another possible reason for the inconsistencies observed among the prior literature.

However, a deeper exploration of the findings for females tentatively suggests avenues for future investigation. In particular, there were several interesting findings: one of these was that three of the models testing the continuous interaction of baseline BMI with job strain were statistically significant even with adjustment for covariates. In connection with one another, they provide a tentative indication that when baseline BMI is operationalised as continuous, differences in the distribution may compound with experiences of job strain to influence future BMI. This was most consistently shown in the analyses where job strain was included as a lagged variable (examining the experience of job strain four years prior with BMI at a subsequent wave). These lagged models demonstrated enough consistency to suggest that future research should continue to explore whether an association of job strain and BMI over time is dependent upon BMI at baseline for females, such that females with greater BMI at baseline who experienced job strain are more likely to have higher BMIs over

time. However, a visual inspection of the interaction (see Figure 5.2 and 5.3) shows that the relationships were not substantively moderated dependent upon baseline BMI, and the slope of the relationship was only slightly attenuated between those who experienced job strain and those who did not. This pattern of results in the lagged models is discussed cautiously in further detail below because the evidence is not strong enough to warrant any conclusions about a relationship; therefore, the suggestion here is that further investigations should be conducted for clarity.

5.6.3 Further Exploration of Lagged Job Strain Model for Females

There was limited evidence of an association between job strain four years earlier (lagged job strain) and BMI that was dependent upon baseline BMI for females. The lags are approximately four years apart, suggesting that there may be a distal relationship across each of the categorical and continuous baseline BMI full sample analyses. The interaction of job strain and continuous baseline BMI was positive and significant in the full sample (for both adjusted and unadjusted models). Unadjusted for other covariates (model A), the categorical baseline BMI interaction investigations also provided some support that job strain may interact with obesity at baseline to be positively related to BMI four years later. However, with adjustment for covariates (model B), the association was attenuated, and further stratification by baseline obesity did not show a statistically significant main effect. However, the stratified analysis was more limited than other analyses, with only 191 females obese at baseline.

In terms of the direction of the significant associations, the continuous full sample analyses showed that the significant interactions were in a positive direction such that the association of experiencing job strain with BMI over time was greater when baseline BMI began higher (an estimated increase of .085 BMI units, given an experience of job strain, for every unit of BMI greater than average at baseline). The evidence from the categorical full

sample analyses provided further context to suggest that females who were obese at baseline may have driven the significance of the interaction observed in the continuous full sample analyses (with an estimated .61 BMI units greater than normal-weight females, given job strain). Finally, while not statistically significant, the stratified analysis of only females who were obese at baseline reported a similarly sized coefficient to that of the full sample categorical analyses (an estimated increase of .66 BMI units associated with job strain) for the main effect of job strain in the unadjusted model (model A).

The findings of Fujishiro et al. (2015) further support the suggestion that future research should investigate whether higher baseline BMIs for females interact with job strain to be associated with even greater BMI increase over time. Fujishiro et al. found a significant interaction of baseline BMI and job strain for females who experienced job strain at baseline and follow-up who had above average BMI at baseline. The size of the association reported by Fujishiro et al. was very modest ($B=.022$ BMI units), smaller than that reported in the current findings. This was despite Fujishiro et al. analysing more than 50,000 females, which likely increased the power of their study. The size of the significant interaction reported by Block et al.'s (2009) analyses of females was similarly small ($B=.18$ BMI units). While this was reported for an interaction of high job demands with increasing BMI at baseline, the consistency of the small estimate of the interaction provides another point for consideration.

To be clear about the interpretation of the current findings for females, the pattern of results described here only considers a possible association and is to be taken with caution. This caution is warranted by the liberal alpha levels for significance that are interpreted (i.e., $p<.1$ in Tables 5.7 and 5.10) and the observation that interactions of job strain with baseline BMI and the main effect of job strain largely became nonsignificant after adjustment for other covariates. Therefore, doubts over whether job strain itself may be associated with BMI in females who have greater initial BMIs, or whether this association can be better explained

by other related variables, must be acknowledged. Despite the need for caution, the results of the analytic models for females suggest a relationship that is theoretically consistent with the explanatory mechanism that, when experiencing stress (including job strain), females who are already obese may further engage in coping mechanisms that contribute to increasing BMI (Järvelä-Reijonen et al., 2016; Nevanperä et al., 2012).

Regarding causality—whether job strain may cause an increase in BMI greater than average depending on baseline BMI—there is a lack of evidence to support a direct or causal role of job strain on BMI over time. That the statistical evidence was attenuated with the inclusion of covariates (see model B of the stratified obese at baseline analyses with females), and the lack of evidence from the other models analysed, is fitting with this interpretation: if a relationship exists, other behaviours related to coping with job strain are likely contributing to BMI increase over time. In summary, the results of the analyses of lagged job strain on BMI over time are not strong enough to suggest that job strain causes an above-average increase in BMI four years later; however, the evidence, although weak, warrants further investigations.

The general random effects and baseline job strain model also showed some evidence of the pattern described above in the lagged model. There was a significant interaction between job strain and continuous BMI at baseline. The positive direction of this relationship suggested that the higher a female's BMI was above average was related to a higher average BMI given an experience of job strain, although the size of the estimated effect was very small (.054 and .151 BMI units for the general random and baseline job strain models respectively). While the positive significant association was still observed with adjustment for the relevant covariates, this finding was not supported by the models including baseline BMI as a categorical variable (both the interaction and the stratified analyses). Thus, the

evidence of a difference in association among job strain and BMI over time being dependent upon lower or higher BMI was not substantiated.

In drawing together the findings for females in this chapter across the differing models using continuous and categorical baseline BMI, the largely null results and limited statistical evidence (specifically, varying and liberal p-values) do not provide consistent evidence of a causal role, or association in general, of BMI at baseline interacting with job strain to influence future BMI.

5.6.4 Strengths and Limitations

The investigations in this chapter make important contributions to the literature and add new perspectives on the role of baseline BMI. The current chapter, as an extension of Chapter 4, has investigated whether a potential association between job strain and BMI over time is moderated by an individual's baseline BMI using four robust analytic models. The varied analytic models used the rich data available to model several possibilities for how a relationship may present over time. These longitudinal models have more power than prior cross-sectional analyses because they model multiple observations for each individual over time (thus providing more data points). In the case of the fixed effects model, between-person variability is partialled out to focus only on within-person change over time, which increases the accuracy of the estimates. To date, similar past investigations of baseline BMI have not used these more sensitive analytic techniques, and nor has the possibility of modelling the relationship in differing ways concurrently been explored and tested. Both job strain and BMI are dynamic variables that are complex and multifactorial; subsequently, the nature and presentation of a relationship that may exist between them is also likely to be complex. It is this complexity, coupled with the uncertainty of the prior evidence regarding a relationship between job strain and BMI in general, that has created the need for more detailed and sophisticated investigations as seen in this and the prior chapter.

This chapter makes an original contribution to the literature in finding no relationship despite the varied modelling techniques adopted. Despite the discrepancy between the current and prior studies' results, the modelling here is a strength that provides insights when considering the causality of a relationship between job strain and BMI over time. For example, each of the prior studies that has found that an association between job strain and BMI over time is dependent upon baseline BMI have only analysed two data points: baseline and follow-up. While a temporal component is built into the design of these studies (collecting a measure of job strain and BMI at baseline and at a later time), it is a strength of the current analyses that both job strain and BMI were analysed over three data points subsequent to baseline data collection. This provided more information on the pattern of job strain and BMI over time, and thus stronger evidence of the temporal nature of any relationship between them.

Both job strain and BMI (i.e., overweight and obesity) have complex aetiological pathways. The anticipated size of an association indicated by the studies that have observed a significant interaction is very small (as discussed in the introduction). Thus, a lack of power may contribute to the null and inconsistent findings among the models that have been reported. In the current study, robust longitudinal analytical models were chosen as the tools of investigation because they were able to use multiple observations over time from each participant. While such features of the analytical methods chosen increase the power of the analyses, it is still a consideration that the sample size may have been insufficient to reliably detect an association across each of the analyses.

Some sample sizes were particularly reduced—especially the male and female samples stratified by baseline BMI category. The obese categories were predictably the smallest categories because BMIs over 30 are towards the end of the BMI continuum. For example, some of the sample sizes were reduced to 172 for males and 179 for females. Given

that the effect of job strain is expected to be very modest in size, requiring sufficient power to detect, with larger sample sizes the results for females in the lagged and broad random effects models may have demonstrated greater consistency.

In the current results, estimates reported were evaluated in combination with the consistency of evidence across the models in accordance with evidence-based methods of evaluation (rather than statistical significance alone) (Wasserstein & Lazar, 2016). For example, in the lagged and general random effects models, the association of job strain with BMI over time for females was either evident (lagged random effects model) or suggested (as in the general random effects model, the p-value approached the significance threshold). In interpreting the results, both the strength and consistency of the evidence were considered, maintaining appropriate caution (i.e., to avoid overinterpreting the statistical significance given that the categorical BMI models showed no evidence). Thus, it was concluded that while no evidence of a relationship between job strain and BMI over time was found to be dependent on individuals' BMIs at baseline, some results suggest pathways for further investigation.

It is also noteworthy that the point on the baseline BMI distribution at which an interaction with job strain was observable in prior studies did not correspond with the cut-points for the WHO-identified BMI categories as used in the current analyses. In fact, the cut-points used by Kivimäki et al. (2006) (BMIs of 22 and 27) and identified by Fujishiro et al. (2015) (BMI above 27) sit roughly in the middle of the normal-weight and overweight BMI categories. Taken together with the evidence for a bidirectional relationship presented in Kivimäki et al. (2006), this indicates that the use of traditional BMI categories may present a confound or 'represent the cancelling out of these opposing relationships' (p. 984). Further, it is noteworthy that without the examination of continuous baseline BMI as the test of an interaction, none may have been detected. Thus, this provides further consideration for a

deeper investigation of the inconsistency reported here among the models using BMI modelled continuously and categorically.

The inconsistency present in the literature regarding an association between job strain and BMI is one of the reasons for the election of multiple analytic models and, in this chapter, to test whether this was moderated by an individual's baseline BMI. However, while an investigation in this manner aims to add clarity to the inconsistent state of the literature, it also presents difficulties. Namely, inconsistencies in the same dataset are difficult to interpret in addition to the inconsistencies already reported in the literature. While inconsistencies between datasets may be explained by more obvious differences (e.g., variable construction, analytic models, and sample characteristics), using the same dataset and methods requires further consideration to explain the inconsistencies. Foremost, it could be that a type one error has occurred, and some statistically significant results were influenced by chance, or a type two error may be present as a result of limited power. The repetition of these analyses with larger sample sizes would assist to determine with greater confidence if either of these errors may be likely.

5.7 Conclusions

The aim of this chapter was to investigate whether an association between job strain and BMI over time may be moderated by baseline BMI. Overall, there was no robust, consistent evidence that baseline BMI altered an association between job strain and BMI over time. While there were some statistically significant findings (mostly for females), the inconsistency in the pattern of results across models, combined with the varying statistical significance reported and the small size of the effect reported, make a null conclusion responsible and appropriate. However, the results reported here suggest that further research is needed to enhance the clarity and confidence of the interpretations and conclusions.

While the null results found here provide information that, despite varied and sensitive analytic modelling, no relationship is present between job strain and BMI over time that is dependent upon differences in individuals' baseline BMI, other studies have found evidence of an association. Thus, further research is required to establish a more reliable and conclusive pattern of results between analytic models (as presented in this chapter) and studies. In line with this, the investigations here into an association between job strain and BMI over time have not been exhaustive. A further possibility is that an association of job strain with BMI over time may be cumulative. Few studies to date have examined whether an accumulation of job strain (i.e., measured via intensity or chronicity or similar) may be related to BMI over time. The next chapter considers this possibility.

Chapter 6: Does Accumulated Job Strain Impact BMI 12 Years Later?

6.1 Chapter Summary

This chapter examines whether the accumulation of job strain over 12 years is associated with BMI at the 12-year follow-up. Most prior literature testing an association between job strain and BMI has done so using only one or two measurements of job strain. Given this limitation and the small body of literature in this area, few studies have conceptualised, discussed, or tested how the relationship between job strain and BMI might build over time. For example, the possibility that experiences of job strain may accumulate over time and demonstrate a dose-response (or other cumulative) relationship with BMI over time has rarely been considered in the literature.

Given that conceptualisations of how job strain may be associated with BMI over time are scarce, the literature review in this chapter begins with a general discussion of how job strain over time might be experienced and how this translates to measurement—specifically, that the duration of strain over time is one way to measure prolonged job strain, but that multiple measurements (or counts) of job strain might also represent either prolonged/chronic strain or multiple experiences of job strain. The long time between measurements is one factor that limits large epidemiological studies from inferring accurately the duration of time under job strain. Thus, this chapter uses the accumulation of job strain *counts or experiences* over time (rather than duration) to investigate the potential for an association with later BMI.

This chapter also reviews prior literature that examines an accumulation of job strain counts in association with increased BMI. To date, it appears that only one study has explicitly examined a dose-response relationship between up to four counts of job strain and

the subsequent odds for obesity. This study is compared with the results from other studies that, while able to contribute some insights, are more limited with just two counts of job strain. The literature review identifies that there are mixed findings as to whether greater counts of job strain are associated with BMI outcomes at follow-up, and whether the pattern of results differs depending on sex or BMI at baseline.

Subsequently, the literature review, analyses, and discussion in this chapter aim to:

1. Discuss how an accumulation of job strain occurs (i.e., differentiate the accumulation of time or counts of job strain);
2. Summarise the evidence for whether cumulative experiences of job strain are associated with future BMI;
3. Examine whether increasing counts of job strain (i.e., accumulation over time) are associated with subsequent BMI—that is, whether there is a dose-response relationship;
4. Investigate whether baseline BMI moderates the accumulation of job strain and BMI over time.

Methods and participants: Data collected at waves one to four from the 40s age cohort of the PATH Through Life longitudinal survey were used in the analyses. At wave one of the study, 1,337 females and 1,193 males participated. The criteria for inclusion in the analyses were that participants were in the 40s age cohort, responded as being employed either full time or part time at all waves, and had information on the job demand and control scales. Those who missed reporting either i) job strain at any wave or ii) BMI at waves one or four (including participants who dropped out completely), and those with a BMI less than 18.5 or greater than 50 were removed from the analyses. This left 525 males and 464 females included in the analyses.

Statistical analyses: Counts of job strain across the study were calculated and categorised as none, one, two, and three or four counts combined. Two sets of analyses were conducted. In the first set of analyses, BMI at wave four (the outcome) was modelled using regression analyses as a function of the number of counts of job strain accrued across the four waves. Baseline BMI was included as a covariate in every model. In the second set of analyses, baseline BMI was interacted with the counts of job strain in regression analyses predicting BMI at wave four. A univariate model and a fully adjusted model (including all covariates) were analysed for each regression analysis, which were stratified by sex.

Results: There was no evidence that an accumulation of job strain—dose-response or otherwise—predicted BMI at follow-up. An interaction between job strain and baseline BMI for males showed that those with higher baseline BMI and who experienced job strain once had lower BMI than those who never reported job strain. However, there was no similar evidence for two or three counts (i.e., a cumulative relationship) of job strain.

Discussion and conclusions: These analyses are one of few to investigate whether the accumulation of job strain experiences is a risk for future BMI increase. No evidence for such a relationship was found, and these null results are discussed with reference to the similarities and differences from other studies. Further, the current study is the first to examine whether counts of job strain predicting follow-up BMI (using more than two counts of job strain) may be moderated by initial BMI (at baseline). Despite the finding that one count of job strain interacted with baseline BMI to predict lower average follow-up BMI among males with higher baseline BMI, the analysis of two and three counts of job strain showed no consistent pattern. In conclusion, this chapter finds no robust evidence that an accumulation of job strain is associated with follow-up BMI.

6.2 Introduction and Background

As discussed in previous chapters, there are mixed findings in the academic literature overall, as well as a number of research gaps regarding the possible relationship between job strain and BMI. One gap is the minimal attention that has been paid to investigating *how* a relationship between job strain and BMI might develop over time. Chapters 4 and 5 explored the effect of recent single experiences of job strain on BMI over time (using random effects, fixed effects and lagged multi-level models to explore a possible association), but multiple experiences may also accumulate over time. That is, cumulative experiences of job strain may be associated with subsequent BMI outcomes. This chapter begins by outlining the definition and possible operationalisations of job strain accumulation over time and dose-response relationships, followed by an overview of the results of past studies.

6.2.1 Defining Accumulation and Dose-Response Relationships

The previous chapters of this thesis discussed the multifactorial, slow-developing nature of weight and BMI change (Lean, 2000; Lovasi et al., 2012; Mozaffarian et al., 2011; Shields, 1999; Sund et al., 2010; Zheng et al., 2017), as well as the evidence linking chronic exposure to stress with weight gain (Geiker et al., 2018; Scott et al., 2012). It is a reasonable hypothesis that with greater (or continued) exposure to job strain over time, there is a greater likelihood that associated changes in BMI (and consequently overweight and obesity) will occur. An accumulation of job strain may occur in varying ways; for example, in a continuous chronic experience of job strain, the length of time under strain may be a critical factor, but multiple discrete experiences—that is, an accumulation of adverse experiences—may also be important. Given the lack of research in this area, it is important to consider what an accumulation of job strain might look like.

The ‘dose-response’ framework describes how an accumulation of job strain can explain future BMI outcomes. A dose-response effect constitutes a predictable, usually

monotonic, change in a dependent variable given each measured exposure to a predictor variable (Mundt, 2005; Steenland & Deddens, 2004). In the current context, it refers to examining increased risk for greater BMI, given each additional experience of job strain. The dose-response relationship has rarely been considered in the job strain and BMI literature because the study elements required to investigate such a relationship are not common. The foremost element is multiple measurements of job strain over time—ideally more than two.

One limitation of the dose-response framework is that studies, including the present thesis chapter, often involve long periods between measurement occasions (e.g., 1–4 years between measurements). It is not possible to accurately describe changes in job strain that may occur within these time intervals, thereby reducing sensitivity to examine the effect of chronic job strain on BMI variation (because start and end periods of job strain may be missed). For example, an approach that counts the number of experiences of job strain over time is unlikely to capture the duration of the job strain at each time point. Given that the data and analyses in the current chapter were not able to measure the duration of job strain at each time point, the focus and approach of the current chapter is to investigate accumulation in reference to an accumulation of *experiences* (i.e., a count of experiences of job strain at each time point), with the reasonable assumption that this is indicative of a greater period of time experiencing job strain (and, by extension, chronic stress at a general level). This approach aligns with the only other comprehensive study that has examined an accumulation of job strain over time and BMI outcomes (cf. Brunner et al., 2007, discussed further below).

6.3 Literature Review

The idea that cumulative exposure to job strain may affect subsequent BMI differently than would a single exposure has only been investigated in a handful of studies. Instead, most longitudinal research in this area has only measured job strain at baseline

(rather than cumulatively) or has only collected data at two time points; thus, it is limited in its contribution to discussions about cumulative hypotheses.

A study that contributes robustly to the possibility of an association between job strain accumulation and BMI outcomes was conducted by Brunner et al. (2007), who had access to seven waves of prospective data (spaced approximately 3–4 years apart) from the Whitehall survey of British civil servants. Job strain was measured four times over a 19-year span, providing a methodological framework to examine a possible dose-response relationship between accumulated job strain and BMI obesity. In this study, the measure of job strain (assessed using a modified version of the JCQ) was combined with a measure of social isolation to indicate whether participants were experiencing ‘iso-strain’ (a variant on the concept of work stress and job strain that suggests that workers experiencing job strain who are socially isolated are the most vulnerable) (Johnson & Hall, 1988; Van Der Doef & Maes, 1999).

Brunner et al. (2007) tested the linear trend in reporting multiple experiences of iso-strain with BMI outcomes—specifically, BMI increase above the obesity threshold of 30—at the 19-year follow up. They found a significant dose-response trend for the cumulative effect of iso-strain on obesity over time in males and for both sexes combined. The estimated linear increase in risk was significant; their estimates were a 16%, 22%, and 70% increase in obesity likelihood for one, two, and three or four reports of job strain across males and females. Additionally, in combined sex analyses and for males separately, having three or four counts of job strain was significantly associated with odds for obesity at follow-up. This finding was independent from the overall increasing linear trend found for increasing counts of job strain. While the linear trend in increasing risk for obesity with increasing counts of job strain was significant, the estimates for obesity risk for one or two counts of job strain were not significantly associated with increased risk of obesity by themselves. This pattern of

results denotes a difference between the increasing overall linear trend in risk and the number of counts of job strain, when predicting risk for obesity.

In unadjusted models for females, Brunner et al. (2007) found three or four reports of iso-strain to be associated with a 338% greater likelihood of BMI obesity (OR 3.38, 95% CI 1.16–9.80), and the odds ratio and confidence interval for one count of iso-strain was also suggestive of an association (OR 1.53, 95% CI 1.01–2.34). However, with adjustment for age and subsequent covariates, no associations were found between the counts of job strain and obesity for females. Further analysis of the overall linear trend found no association of increasing counts of iso-strain with obesity at follow-up. Thus, the only evidence for a dose-response relationship of job strain with obesity at follow-up in females was found when females were combined in analyses with males. That there was no evidence for females in analyses stratified by sex reasonably indicates that the data for males may have driven the significance of the estimates observed in the combined sex analyses. However, it must be noted that the sizes of the estimates in the combined sex analyses were equivalent to those of the stratified analyses: no dilution of the association was observed by combining sexes.

Further analyses conducted by Brunner et al. (2007) removed those who were already obese at baseline from the sample to examine incident obesity at follow-up. These analyses showed only a modest adjustment of the results with all participants. This finding provides support for an accumulation of iso-strain to be associated with both incident obesity and the further development of established obesity. Accordingly, Brunner et al. concluded there was strong evidence for a causal role of job strain in the development of obesity (and thus increasing BMI) over a significant portion of working life (participants were aged 35–55 at baseline and sampled across 19 years). Importantly, their results evidence a trend in the accumulation of job strain counts over time, having observed increased risk for obesity with increasing counts of job strain.

6.3.1 Studies with Only Two Job Strain Measurements

The study conducted by Brunner et al. (2007) appears to be the only published prospective population-based study to have observed job strain across more than two data points and to have specifically tested an accumulation of job strain with BMI obesity. In lieu of further studies testing accumulation directly, the results of studies with data on job strain at two time points may offer some insights into whether an accumulative relationship exists. Few studies with two measurements of job strain have examined differences in whether none, one, or two counts of job strain are associated with BMI (i.e., Eek & Östergren, 2009; Fujishiro et al., 2015; Ishizaki et al., 2008; Klingberg et al., 2019; Niskanen et al., 2017; Nyberg et al., 2012). In the present chapter, these studies are reviewed in the context of an association between follow-up BMI and ‘chronic’ or ‘persistent’ job strain (defined by two counts of job strain), thus offering some insights into whether an accumulation of job strain may be associated with BMI over time.

A large meta-analysis by Nyberg et al. (2012) analysed data on job strain and BMI obesity at two time points from 42,222 male and female participants sampled from four separate studies. The authors tested whether the odds for incident obesity at follow-up (among those who were not obese at baseline) significantly changed depending on job strain pattern: no job strain at baseline and follow-up, job strain at baseline only, job strain at follow-up only, and persistent job strain at baseline and follow-up. They found that the odds for BMI increase above 30 (obesity) was 18% higher among those who reported job strain at follow-up only. They did not find that job strain at baseline or persistently at both measurements predicted obesity at follow-up. Thus, while there was evidence that job strain and obesity tended to co-occur, the results did not support a causal association of job strain with increasing BMI. The authors further concluded that there was no evidence for a dose-response association because repeated measures of job strain (across two time points:

baseline and follow-up) were not associated with greater odds of obesity at follow-up. These results of Nyberg et al. reflect males and females combined, as the interaction of job strain and sex with risk for BMI obesity was not significant.

However, in another analysis of combined sex data, a more recent study by Klingberg et al. (2019) reported evidence that conflicted with Nyberg et al.'s (2012) results. Klingberg et al. collected data on weight change at three points—with each data point measured 10 years apart—but analysed just two measurements of job strain taken at baseline and at the first 10-year follow-up. They analysed whether persistent job strain (at baseline and 10-year follow-up) was associated with increased odds of major weight gain at the 20-year follow-up. Their analysis of 1,747 male and female participants indicated that those with persistent job strain had the greatest likelihood of major weight gain at follow-up (53% increased likelihood). However, when Klingberg et al. further tested persistently high job strain stratified by sex, they found persistent job strain to predict major weight gain among females only (79% increased likelihood).

Broadly, the combined sex results of Klingberg et al. (2019) are in line with those of Brunner et al. (2007), finding that higher counts of job strain are associated with increased BMI at follow-up. While the results of Nyberg et al. (2012) are somewhat at odds with this finding, their combined sex analyses do suggest possible sex differences that may present a confound when sexes are analysed together. For example, despite the significance of their combined sex analyses, the results of Brunner et al. suggest a significant dose-response trend for males only. In contrast to Brunner et al., Klingberg et al. found persistent job strain to significantly predict major weight gain in females, but not in males. These conflicting findings are difficult to interpret and may arise due to measurement differences (i.e., slightly different measures of job strain and differing adiposity outcomes) or some further context that was not addressed. While the findings of Nyberg et al. do not indicate an interaction by

sex, the results of Brunner et al. and Klingberg et al. suggest value in stratifying analyses by sex. Given these contrasting findings, further exploration of the literature for each sex is required.

6.3.1.1 Results for Males

In their sex-stratified analyses, Klingberg et al. (2019) analysed 843 males who reported job strain at baseline and 10-year follow-up to determine the likelihood of major weight gain at the 20-year follow-up. However, the risk for major weight gain was not significant for males when analysed separately from females. Three other studies that examined the association of persistent job strain at baseline and follow-up with BMI in males were Ishizaki et al. (2008), Niskanen et al. (2017), and Eek and Östergren (2009). Among these, none found any evidence to support an accumulative association of job strain with increased BMI. Ishizaki et al. (2008) studied 2,200 Japanese males aged 30–53 years twice over six years. They found that BMI change across the study period did not differ according to zero, one, or two reports of job strain for males. Eek and Östergren (2009) found a similar null result when analysing 4,424 Swedish males who they sampled twice over a five-year period (job strain reported at either baseline or follow-up, or at both times). They found no evidence for an association of BMI change over the five-year period with a cumulative pattern of job strain.

In a study of 747 employed Finnish males, Niskanen et al. (2017) analysed patterns of job strain over time—no job strain at baseline or follow-up, a change between baseline and follow-up, and those with high job strain at each measurement—in relation to major weight gain (defined as a 10% gain from baseline to follow-up). The study spanned approximately 12 years, and two measurements of job strain were used to predict the odds of major weight gain at a third measurement occasion. In testing persistent job strain, the authors reported no findings indicating an accumulation of job strain. The components of job strain, high job

demands and low job control, were also not associated with increased risk for major weight gain.

Thus, the existing findings for males regarding an accumulation of job strain (or evidence from the component scales) with BMI outcomes are mixed. The findings of Brunner et al. (2007) and Klingberg et al. (2019) offer the only supporting evidence for an association in males of accumulative job strain, or its components, with BMI increase over time. Given the limited evidence that is available, further research is needed to clarify whether experiences of job strain may accumulate to drive future BMI outcomes for males.

6.3.1.2 Results for Females

Similar to the results for males, there are inconsistencies present in the literature for females. For instance, in the high-quality study by Brunner et al. (2007), there was no evidence for the existence of an accumulative association for females independent from males. Consistent with this, Ishizaki et al. (2008) found no relationship between counts of job strain and BMI increase when analysing 1,701 females aged 30–53 at baseline who were working in a rural Japanese factory. They used two measurements of job strain taken six years apart and examined whether zero, one, or two reports of job strain were associated with average baseline BMI or average BMI change across the six years. However, this study is the only one to report entirely null findings for females. Four further studies (Eek & Östergren, 2009; Fujishiro et al., 2015; Klingberg et al., 2019; Niskanen et al., 2017) found evidence that persistent job strain was associated with greater BMI change than was one or no counts of job strain. This offers some evidence for an accumulation of job strain among females.

Eek and Östergren (2009) analysed 5,488 Swedish females at two time points five years apart. They tested whether job strain at both baseline and follow-up, baseline only, or at follow-up only, was associated with greater BMI change compared to not reporting job strain. They found that BMI increase for middle-aged females (aged 40–59) was greatest among

those who reported persistent job strain (.85 BMI change estimated) and second greatest among those with baseline job strain only (.72 estimated BMI change), and that each BMI increase was significantly different from the average BMI change (.43) for females who had not reported job strain at all.

Fujishiro et al. (2015) analysed data on job strain and BMI for 52,656 female nurses at two occasions, four years apart. They found the same pattern identified by Eek and Östergren (2009); compared with those who had not experienced job strain at baseline or follow-up, those who had experienced job strain once had a significant increase in BMI (+.063–.074 BMI change), and those who reported persistent job strain experienced the greatest BMI increase (+.118 BMI). Both Eek and Östergren (2009) and Fujishiro et al. analysed the change in BMI over the study period as a continuous outcome of change in job strain pattern (no job strain at either measurement, job strain at one measurement time, or persistent job strain at each measurement occasion). Their results showed that the average BMI change estimated for females who reported persistent job strain was higher than for those reporting a single incidence of job strain, thus offering some support for an incremental increase in BMI over time with cumulative counts of job strain.

In the third study to report on BMI and job strain for females, Klingberg et al. (2019) collected data at three time points, measured 10 years apart. They collected data on body weight at each measurement but used just two measurements of job strain taken at baseline and at the first 10-year follow-up. In a sample of 904 females, the authors analysed whether persistent job strain at baseline and at the 10-year follow-up was associated with increased odds of major weight gain at the 20-year follow-up. Klingberg et al. found that those reporting job strain persistently had the highest odds of major weight gain across the study (79% increased odds).

In a fourth study, Niskanen et al. (2017) also analysed patterns of job strain over time (detailed above) in association with major weight gain (defined as a 10% gain from baseline weight) at follow-up. The study spanned approximately 12 years, and two measurements of job strain were used to predict the odds of major weight gain at a third measurement time. Niskanen et al. found a weak association of persistently high job strain with increased risk for major weight gain among females who were normal weight at baseline, however after adjusting for covariates, the significance of this relationship was attenuated. Niskanen et al. did not report any other findings indicating a main effect of job strain accumulation across the BMI distribution. They also tested the components of job strain and reported some evidence that persistently high job demands were associated with major weight gain in females, but there was no evidence for an effect of persistently low job control on BMI.

Taken together, the results of these studies present some evidence that there is an increased risk of greater BMI increase for females who report job strain twice (persistently). However, the use of only two measurements of job strain limits a discussion of accumulation, and some inconsistencies are present among the studies. A deeper investigation reveals some contextual factors that may underlie the findings, including that there may be some evidence for an interaction between baseline BMI with increasing counts of job strain on later BMI outcomes. A discussion of this possibility and other contextual factors is presented in the following sections.

6.3.2 Evidence for an Interaction of Baseline BMI and Accumulation of Job Strain

Brunner et al. (2007), Fujishiro et al. (2015), Klingberg et al. (2019), and Niskanen et al. (2017), further tested whether an interaction of job strain with baseline BMI may be evident. Each study found that the strength of association between an accumulation of job strain counts differed dependent upon females' BMI at baseline. Fujishiro et al. tested the interaction of baseline BMI with one or two counts of job strain compared to females who

had not experienced job strain, finding that as baseline BMI increased above average, the strength of the association between job strain with greater follow-up BMI increased.

However, this interaction was only significant for females who experienced persistent job strain (reported two counts of job strain over time), and not for those who experienced job strain just once at either baseline or follow-up.

Similarly, Klingberg et al. found a significant interaction when testing persistently high job demands in females (they did not report testing an interaction of job strain counts with baseline BMI). When stratifying their analyses by baseline BMI category (females whose baseline BMI was less than 25, and those whose baseline BMI was greater than 25), they found that persistently high job demands were associated with 313% increased odds of major weight gain for females who were overweight or obese at baseline (BMI greater than 25), and that persistently high job demands were not significant for those whose baseline BMI was normal (less than 25).

The structure of the study and analyses by Klingberg et al. (2019) closely resembled that of Niskanen et al. (2017), who also analysed the association of job strain with major weight gain in analyses stratified by baseline BMI. Niskanen et al. used the same cut-point for stratification as Klingberg et al. (BMI above and below 25), but found only weak evidence that persistent job strain was associated with major weight gain, and this finding was attenuated when adjusted for covariates. Niskanen et al. also reported that an increase in job strain over time (for females with no job strain at baseline) was associated with major weight gain, and that when stratified by baseline BMI, this was only the case for females who were overweight and obese at baseline. However, Niskanen et al. (2017) found no evidence that persistent job strain over time was associated with major weight gain dependent upon baseline BMI.

Similar to Klingberg et al. (2019), Niskanen et al. (2017) tested job demands and job control in interaction with baseline BMI; however, their results were discrepant. For females with a BMI greater than 25 at baseline, there was a significant association with major weight gain only when there was an increase in job demands over time. However, in analyses not stratified for females' baseline BMI, Niskanen et al. reported persistently high job demands to be associated with major weight gain. The stratification revealed that a change in the experience of high job demands was associated with major weight gain for females who were initially overweight or obese. Interestingly, the estimated likelihood of major weight gain in females whose BMI was greater than 25 at baseline increased to 52%. This is in comparison with prior analyses across the entire BMI distribution at baseline, whereby persistently high job demands were associated with a 22% increased likelihood of major weight gain. The testing of persistently high job demands in interaction with baseline BMI by both Niskanen et al. and Klingberg et al. provides evidence that flow-on effects may drive an interaction of job strain with major weight gain (and thus BMI) depending on baseline BMI. However, the inconsistency of the results in Niskanen et al. and the contrast with those of Klingberg et al. is difficult to explain and requires further investigation.

Brunner et al. (2007) stratified their analyses at the threshold of obesity (BMI of 30) to examine prospective risk for incident obesity amongst those non-obese at baseline. However, they did not find any significant increase in risk for obesity with increasing counts of job strain. Thus, Brunner et al.'s results showed no difference in the accumulation of job strain with risk for obesity in those who were normal weight or overweight (combined) at baseline. However, as indicated by the results of Fujishiro et al. (2015) and Klingberg et al. (2019), an interaction might be more likely in those of higher BMI (rather than those with a BMI of less than 30). Thus, combining normal-weight and overweight individuals may have confounded the sample analysed by Brunner et al.. The results of Fujishiro et al. (2015) and

Klingberg et al. (2019) suggest that an accumulation of job strain, or its components, on BMI over time differ depending on higher BMIs.

However, this was specifically for females, and the evidence for an interaction with baseline BMI appears to be limited for males. While Klingberg et al. tested interactions with BMIs above and below 25, they presumably found no evidence for an interaction in males because none was reported. For males, Brunner et al. showed no modification of the accumulative relationship when removing males already obese at baseline. The only other evidence available for males, found in Niskanen et al., did not support a relationship of accumulated job strain (even persistent job strain) with major weight gain. However, Niskanen et al. showed a significantly increased likelihood of major weight gain (293% increase) given an increase in high job demands over time that was specific to overweight and obese males at baseline. This is the same pattern as that found for females. However, among males who were normal weight at baseline, Niskanen et al. also reported a 454% increased risk of major weight gain for males whose job demands decreased over time (from high job demands at time one to low job demands at time two). While these results provide some evidence for an interaction of baseline BMI with changing job demands among males, the findings specific to job strain seem to show more evidence for an interaction with baseline BMI for females than for males.

Evidence for an interaction of job strain and baseline BMI was presented in Chapter 5, and although no evidence for an interaction was found within the PATH dataset, some peculiarities in the results for females would benefit from further research. In addition, the present chapter focuses on a different way in which job strain and baseline BMI may interact; that is via an interaction with an accumulation of job strain—a question that the PATH dataset is well placed to investigate.

6.3.3 Further Contextual Factors for Consideration

6.3.3.1 Size of the Effect

There are mixed findings regarding the size of the relationship between accumulated job strain and increased BMI where evidence has been found for females. Eek and Östergren (2009) reported that females with persistently high job strain gained an average .42 BMI units more than those who had not experienced job strain, and just .13 BMI units more than those who had reported job strain once at baseline. Fujishiro et al. (2015) reported smaller average increases than Eek and Östergren, finding that the average estimate for persistent job strain was .118 BMI units higher than those with no job strain at either baseline or follow-up, and just .063–.074 BMI units higher for one count of job strain. Although these estimates are statistically significant, they are quite small, especially when considering the period over which the average increase was observed (approximately 4–5 years). Klingberg et al. (2019) show a moderate increase in risk for major weight gain in females (79% increased odds). The combined sex results of Brunner et al. (2007) show a moderate association of job strain accumulation with obesity (with obesity a more extreme BMI outcome), which supports Klingberg et al.'s findings. However, their analyses with females only do not support this; thus, there is mixed information regarding the size of the possible association for females. The information available in the literature also suggests that the size of the relationship, if present, may depend on baseline BMI. For example, when analysing those whose BMI was above 25 at baseline (overweight and obese), Klingberg et al. reported that the odds of major weight gain were 313% higher given persistently high job demands.

Fewer studies offer support for an association of job strain accumulation with BMI in males, but those that do so have found that the size of the association is moderate. For example, Brunner et al. (2007) found that greater counts of job strain were associated with increased risk for obesity (15%, 52%, 64% increased odds given 1, 2, 3-4 counts of job strain

respectively). In contrast, there was limited evidence for males in the study by Klingberg et al. (2019). While they reported persistent job strain and low job control to predict increased odds for major weight gain (53% and 44% increased odds for persistent job strain and persistently low job control, respectively), the finding for job strain was only in combined sex analyses, and not when males were tested separately. No other studies offer support for an accumulative association of job strain with BMI for males.

6.3.3.2 Length of Follow-Up

The length of follow-up of each study may help to understand the difference in magnitude between evidence for females and between sexes. The length of follow-up in the studies of Fujishiro et al. (2015) and Eek and Östergren (2009) was four years and five years respectively, which was lower than in Klingberg et al. (2019) (who measured weight gain over 20 years) and Brunner et al. (2007) (who had a 19-year follow-up). With less time for BMI to increase, it is understandable that average estimates of BMI change, and any increase above average that is associated with job strain is likely to be lower in studies with a shorter follow-up.

The length of time over which BMI is measured after the measurement of job strain counts could also explain the larger effect sizes of Klingberg et al. (2019) and Brunner et al. (2007). In each study, the follow-up BMI and weight were measured long after the final measures of job strain: a 10-year delay in Klingberg et al. and an approximate 4–5-year delay in Brunner et al. This is a further important difference that separates these two studies from others that measured job strain and BMI concurrently, because measuring job strain and BMI concurrently may not allow sufficient time to observe the effect of accumulation of job strain on BMI at follow-up. Accordingly, a delay between the measurement of job strain and the measurement of follow-up BMI (such as in Klingberg et al. and Brunner et al.) may be an

important consideration for studies with just two measurements of job strain, especially in the context of examining an accumulation of job strain with later BMI.

6.3.3.3 Measurement of BMI

The different BMI-related outcomes employed in each study is another factor that may have influenced the findings reported. Klingberg et al. (2019) and Niskanen et al. (2017) used a categorical weight gain outcome—‘major weight gain’—determined by an increase of more than 10% of body weight at baseline and the third and final follow-up. Contrastingly, Eek and Östergren (2009) and Fujishiro et al. (2015) analysed BMI change continuously and thus reported far smaller average increases to be associated with persistent job strain. Numerous possibilities arise from these differences, including that the strength of association observed by Klingberg et al. and Niskanen et al. was influenced by setting a threshold that selected for stronger associations: given a lower threshold, a smaller or weaker association may have presented; or conversely, the strength of association may have increased if Eek and Östergren, and Fujishiro et al., had used a similar categorical outcome.

This contextual information may also be relevant when considering the findings of Brunner et al. (2007), who found no support for an accumulation of job strain counts with obesity when analysing females separately from males, but reported a stronger significant relationship when analysing the sexes together. If Brunner et al. used a continuous outcome of BMI change over time, or a less extreme threshold than entrance into obesity, such as that used in Klingberg et al. (2019), a different result may have presented. For example, job strain accumulation may have been related to major weight gain, but not to becoming obese.

6.4 Summary of Literature Review and Aims

There are mixed findings regarding whether an accumulation of job strain experiences is associated with BMI. Possibly there are important differences by sex, but even within sex-stratified analyses, there are mixed findings as to whether increasing counts of job strain

accumulate in association with BMI increase over time. A contributing factor to the inconsistencies is the lack of literature that can robustly answer whether job strain experiences accumulate; therefore, further research is required.

Although job strain is treated as a single experience/exposure or multiple discrete exposures/counts in existing research, job strain experiences in real life vary in their duration, and measures rarely capture whether the strain has occurred discretely or continuously. In the absence of an accurate measure of the duration of job strain, duration and chronicity are better represented by a greater number of assessments/time points. Indeed, Brunner et al.'s (2007) four assessments of job strain and explicit testing of the trend to test the 'accumulation' of job strain, garners more confidence than other studies to date. Longitudinal research requires more than one observation in time, and while some studies have measurements at two time points available, in most instances where psychosocial risks are involved, a greater number of observations is preferred, especially for examining risks concerning accumulation or chronicity.

Although Brunner et al.'s (2007) research still adopted a count variable to represent accumulated job strain, the longer duration of the study allowed more time for change in BMI, as well as more data on experiences of job strain, thereby providing a more appropriate methodology for specifically assessing accumulation. In line with this, in a meta-analysis of studies examining the association between stress and adiposity over time, Wardle et al. (2011) found that studies with follow-up lengths longer than five years were more likely to detect a significant positive association between stress and increased adiposity, and that the effect size detected was larger in comparison with lower-quality and shorter studies (also supported in a review of work stress and adiposity by Solovieva et al., 2013). However, this finding must be interpreted with the knowledge that Wardle et al. included both general stress

and work stress measures in these estimates, whereas job strain is the focus of the current thesis.

Overall, while robust longitudinal research by Brunner et al. (2007) shows support for a dose-response relationship between accumulation in job strain and BMI increases over time, there is not enough literature with multiple data points available to be confident that this is the case more broadly. The PATH Through Life study, with four available time points on job strain and a long follow-up length of 12 years, provides a unique opportunity to examine this question in the current thesis. The analyses in this chapter examine whether multiple counts of job strain, as an indicator of greater exposure to job strain over time, have a cumulative effect on BMI outcomes. Individual counts/exposures of job strain (0–4) are analysed for a cumulative relationship with BMI at the 12-year follow-up. Further analyses aim to explore whether this is dependent on baseline BMI (given that the prior findings provide some evidence that baseline BMI may be important). That is, the current chapter aims to answer the following questions:

1. Are increasing counts of job strain over time associated with BMI outcomes? Is there evidence for a dose-response relationship, or a differently structured cumulative effect?
2. Does baseline BMI moderate a relationship between the accumulation of job strain and BMI over time?

6.5 Methods

6.5.1 Participants

The sample for this analysis chapter was taken from the 40s cohort of the PATH Through Life study. The ages of participants ranged from 40 to 44 years at wave one to 52–56 years at wave four. At wave one, 1,337 females and 1,193 males participated; however, any person who missed reporting on the job strain measure at any wave or BMI at wave one

or four (including participants who dropped out completely), and those with a BMI less than 18.5 and greater than 50 (to reduce error, consistent with all analyses in this thesis), were removed from the analysis. This left 525 males and 464 females who were ‘complete cases’ at wave four (because BMI outcome was assessed at wave four); that is, these participants had information on job strain at every wave (Table 6.1 shows the number of males and females included in the sample by count of job strain). While complete information across all waves for the covariates was not an inclusion criterion, the 525 males and 464 females had no further missing information on any covariate.

Studies on longitudinal retention show that active respondents often have different health and economic profiles when compared with those who drop out (Teague et al., 2018). Tables 2.4 and 2.5 in Chapter 2 show test results for variables of interest measured at baseline between those who were included in the analyses as a complete case and those who dropped out at one, or multiple, waves. These analyses showed that differences in various health and economic variables were apparent between those who dropped out and those who were active until the completion of the study, and that some differences between males and females were present. However, importantly, there were no significant differences in job strain and BMI between those who dropped out at baseline and those who did not—that is, the sample analysed in this chapter.

6.5.2 Measures

The key measures used throughout all analyses chapters in this thesis were described in detail in Chapter 2. However, a brief overview of each of the independent, dependent, and covariate variables, and specific information pertaining to this chapter, is provided below.

6.5.2.1 Job Strain Accumulation

The accumulation of job strain was the main independent variable investigated. First, to create an indicator of accumulated job strain over time, the binary variable representing

‘high’ versus ‘low’ job strain adopted in the previous two longitudinal analysis chapters was calculated for the sample at each wave (see Chapter 2 for a description of how this variable was calculated). A count variable was then calculated representing the number of waves at which participants experienced high job strain. The counts of job strain over the four waves were coded into four categories: zero counts (reference group), one count, two counts, and those who reported job strain three or four times were combined and coded together to maximise numbers.

6.5.2.2 BMI

BMI at wave four was the dependent variable investigated. BMI was calculated using the participants’ weight in kilograms divided by their height in metres squared (weight [kg]/height [m²]). Participants self-reported their weight at every wave to the nearest kilogram. Their height was self-reported only at waves one and two. Wave one height was used to calculate participants’ BMI because it had a higher response rate than wave two; however, when wave one data were missing, wave two data were used instead, if available.

6.5.2.3 Covariates in Fully Adjusted Analyses

The covariates included in the analyses were the same as those used in the prior analysis chapters: years of education, financial stress (as an indicator of SES), parent status, work hours, exercise level (low, moderate, high), current smoking status, and physical and mental health. In the analyses, the data for these covariates were selected from wave four, the same wave as the dependent variable BMI, except for years of education (taken at wave two). The covariate estimates reported throughout are not intended to be interpreted as total-effects estimates commensurate with the primary variable of interest, job strain (Westreich & Greenland, 2013; see Chapter 2 for a further explanation of the covariate estimates reported). Baseline BMI (measured at wave one) was also included as a covariate to adjust for

differences in initial BMI levels. As in all other chapters, BMI was self-reported by participants and kept as a continuous measure.

6.5.3 Statistical Analysis

6.5.3.1 Data Preparations

A scatterplot of BMI at wave four with BMI at baseline identified outliers via visual inspection. Standardised residuals were calculated, which confirmed these observations as outliers, identifying four male and six female participants with a score greater than three standardised residuals, and each of the analyses were conducted without these outliers. The removal of these outliers did not change the magnitude, significance, or pattern of the results; thus, these outliers were maintained in the analyses. However, scatterplots of BMI at wave four with baseline BMI, that were stratified by each count of job strain, identified three outliers for females reporting three or four counts of job strain. The removal of these outliers modified the significance and magnitude of the average estimates predicted for the females who had experienced three or four counts of job strain; thus, these results are presented below in tandem with the results including these three outliers. For males and females separately, scatterplots of BMI at wave four with baseline BMI for each other count of job strain showed adequate linearity and normality.

6.5.3.2 Analytic Plan One: Accumulation of Job Strain on BMI Analyses

The first series of analyses examined the relationship between accumulation in job strain with BMI at wave four by testing the cumulative counts of job strain reported over the four waves of data. The coded job strain categories were first entered into a univariate linear regression (model A) to predict differences in BMI at wave four between these groups. Baseline BMI was also entered as a covariate in this initial model. Second, relevant covariates at wave four were added to the model to adequately adjust for their possible influence (model B).

6.5.3.3 Analytic Plan Two: Interaction of Job Strain Counts with Baseline BMI on BMI Analyses

As outlined in the previous chapter and above, there is some evidence that baseline BMI may moderate an association of job strain and subsequent BMI. To test whether an interaction was present, the analyses were repeated with the inclusion of an interaction term (baseline BMI was interacted with the job strain count variable). In the interaction term with job strain, baseline BMI was maintained as a continuous variable because cell sizes were too small when baseline BMI was separated as a categorical variable.

6.6 Results

6.6.1 Descriptive Statistics by Cumulative Job Strain Counts

Table 6.1 shows the number of males and females analysed who reported zero, one, two, or three or four counts of job strain over the study period, showing that more than one-third of males and almost half of females experienced job strain at least once over the 12-year period. Only 12.76% of males reported experiencing job strain more than once; in comparison, 20.90% of females reported at least two experiences of job strain.

Tables 6.2 and 6.3 show the descriptive statistics for each variable included in the analyses by category of job strain count. At both baseline and wave four, BMI was not significantly different between those reporting different counts of job strain for males or females. Mental and physical health differed significantly by counts of job strain for females, with average mental health and physical health significantly declining with increasing counts of job strain. However, in males, those reporting two counts of job strain had the lowest mental and physical health average. There was no indication that proportions of smoking differed by counts of job strain in male or female participants. Financial problems for females differed statistically by counts of job strain, with those reporting financial problems also indicating experiencing one, two, or three or four counts of job strain. For both males and

females, there was no indication that work hours was associated with higher counts of job strain.

Table 6.1

Total Accumulation of Job Strain: Number of Counts of Job Strain Across Four Waves

Job strain counts	Male	Female
0	333 (63.43%)	247 (53.23%)
1	125 (23.81%)	120 (25.86%)
2	37 (7.05%)	60 (12.93%)
3/4	30 (5.71%)	37 (7.97%)
Total N	525	464

Note. Only those who responded on BMI and job strain at all four waves were included.

Table 6.2*Males: Wave Four Descriptive Statistics by Number of Job Strain (JS) Counts*

Job Strain counts		0 counts of JS		1 count of JS		2 counts of JS		2/3 counts of JS		Sig.
		M(SD)		M(SD)		M(SD)		M(SD)		
Total N		333		125		37		30		
Continuous variables										
BMI at W4		27.65 (4.09)		27.55 (4.13)		27.89 (3.57)		27.99 (3.78)		0.937
Baseline BMI		26.71 (3.71)		26.81 (4.28)		26.80 (3.12)		26.98 (3.56)		0.979
Rand MHC		51.86 (8.57)		49.04 (8.90)		45.67 (10.18)		47.90 (8.80)		<.001
Rand PHC		51.82 (7.27)		50.03 (7.94)		49.16 (7.31)		51.40 (7.32)		0.043
Years of education		15.03 (2.23)		14.90 (2.11)		15.00 (2.01)		14.98 (2.02)		0.966
Job hours		43.79 (11.72)		42.44 (12.27)		44.68 (8.85)		48.38 (8.95)		0.084
Categorical variables		%	N	%	N	%	N	%	N	Sig.
Smoke	No	63.2%	309	23.5%	116	7.6%	37	5.7%	28	0.385
	Yes	66.7%	24	27.8%	10	0%	0%	5.6%	2	
Children	No	63.2%	296	23.5%	110	7.5%	35	5.8%	27	0.717
	Yes	64.9%	37	26.3%	15	3.5%	2	5.3%	3	
Exercise	Low	57.7%	79	25.6%	35	10.2%	14	6.6%	9	0.522
	Mod	63.3%	133	24.3%	51	6.2%	13	6.2%	13	
	High	68.0%	121	21.9%	39	5.6%	10	4.5%	8	
Finance probs	No	63.9%	299	23.7%	111	7.3%	34	5.1%	24	0.386
	Yes	59.7%	34	24.6%	14	5.3%	3	10.5%	6	

Note. Descriptive statistics are from wave four, except for education (measured at wave two) and baseline BMI (wave one). ANOVA or chi-square tests were used as appropriate to determine the significance of any differences between counts of job strain.

Table 6.3*Females: Wave Four Descriptive Statistics by Number of Job Strain (JS) Counts*

Job Strain counts		0 counts of JS		1 count of JS		2 counts of JS		2/3 counts of JS		Sig.
		M(SD)		M(SD)		M(SD)		M(SD)		
Total N		247		120		60		37		
Continuous variables										
BMI at W4		27.03 (5.82)		27.47 (5.34)		27.55 (4.99)		27.61 (6.40)		0.833
Baseline BMI		25.35 (5.15)		25.52 (4.27)		25.41 (4.27)		25.17 (4.17)		0.980
Rand MHC		51.09 (7.90)		49.85 (8.12)		49.00 (9.00)		45.75 (9.92)		0.002
Rand PHC		50.97(7.75)		49.00 (8.70)		49.13 (10.18)		47.43 (10.75)		0.033
Years of education		14.85 (2.14)		14.37 (2.22)		14.84 (1.82)		14.66 (2.34)		0.235
Job hours		37.56 (12.23)		36.46 (13.68)		39.60 (11.92)		41.87 (12.35)		0.087
Categorical variables		%	N	%	N	%	N	%	N	Sig.
Smoke	No	54.8%	235	24.7%	106	12.8%	55	7.7%	33	0.107
	Yes	34.3%	12	40.0%	14	14.29	5	11.4%	4	
Children	No	54.1	231	25.1	107	12.7	54	8.2	35	0.430
	Yes	43.2	16	35.1	13	16.2	6	5.4	2	
Exercise	Low	51.8	99	27.6	53	12.6	24	7.9	15	0.886
	Mod	54.8	92	26.2	44	11.3	19	7.7	13	
	High	53.3	56	21.9	23	16.2	17	8.6	9	
Finance probs	No	54.0	223	26.9	111	12.4	51	6.8	28	0.022
	Yes	47.1	24	17.7	9	17.7	9	17.7	9	

Note. Descriptive statistics are from wave four, except for education (measured at wave two) and baseline BMI (from wave one). ANOVA or chi-square tests were used as appropriate to determine the significance of any differences between counts of job strain.

6.6.2 Modelling the Results of Job Strain Accumulation with BMI at Wave Four

Linear regression analyses were used to investigate the relationship between the accumulation of job strain counts over the 12-year period in association with BMI at wave four by modelling zero, one, two, or three and four counts of job strain in association with BMI at wave four (see Tables 6.4 and 6.5). In univariate (model A) and multivariate (model B) models, no significant association with BMI at wave four was found for any number of counts of job strain for males or females. While not significant, the analyses with females showed that the estimates for one, two, and three or four counts of job strain increased in size with increased counts. However, analyses with the three outliers removed (see Table 6.6) showed that the estimate for BMI at wave four for three or four counts of job strain was attenuated to approximately the size of that estimated for just one count of job strain. While the effects for covariates are not the focus of this thesis, it is interesting to note that for males, higher BMI at wave four was associated with higher baseline BMI, low physical activity, poorer physical health, lower education, and more working hours per week. For females, higher BMI at wave four was also associated with all of these covariates, except for education.

Table 6.4*Male: Regression of Job Strain Counts on BMI at Wave Four*

Male		Model A				Model B			
		B	P		CI95	B	P		CI95
Job strain counts	0	Reference							
	1	−0.188	0.475	−0.705	0.329	−0.231	0.374	−0.740	0.279
	2	0.167	0.700	−0.687	1.022	−0.025	0.954	−0.878	0.828
	3/4	0.108	0.821	−0.831	1.048	−0.057	0.903	−0.984	0.870
Baseline BMI		0.834	0.000	0.778	0.891	0.800	0.000	0.743	0.857
Smoke	No	Reference							
	Yes					−0.607	0.162	−1.458	0.245
Children	No	Reference							
	Yes					0.010	0.976	−0.675	0.696
Exercise	0	Reference							
	1					−0.071	0.795	−0.609	0.467
	2					−0.642	0.030	−1.219	−0.064
Finance probs	No	Reference							
	Yes					−0.225	0.530	−0.928	0.478
RAND-MHC						0.009	0.527	−0.019	0.037
RAND-PHC						−0.041	0.018	−0.075	−0.007
Education						−0.139	0.007	−0.239	−0.038
Job hours						0.032	0.001	0.014	0.051
Model constant		27.867	0.000	27.597	28.138	30.509	0.000	28.169	32.848
Total observations, N		525				525			

Table 6.5*Female: Regression of Job Strain Counts on BMI at Wave Four*

Female		Model A				Model B			
		B	P		CI95	B	P		CI95
Job strain counts	0	Reference							
	1	0.264	0.423	−0.383	0.910	0.182	0.575	−0.455	0.819
	2	0.450	0.291	−0.386	1.286	0.370	0.374	−0.447	1.187
	3/4	0.748	0.152	−0.276	1.772	0.493	0.342	−0.526	1.511
Baseline BMI		1.000	0.000	0.944	1.057	0.941	0.000	0.884	0.999
Smoke	No	Reference							
	Yes					−0.653	0.207	−1.669	0.363
Children	No	Reference							
	Yes					−0.482	0.334	−1.462	0.497
Exercise	0	Reference							
	1					−0.691	0.030	−1.315	−0.067
	2					−1.101	0.003	−1.831	−0.372
Finance probs	No	Reference							
	Yes					0.351	0.427	−0.517	1.220
RAND-MHC						0.024	0.216	−0.014	0.062
RAND-PHC						−0.072	0.000	−0.108	−0.035
Education						−0.064	0.325	−0.191	0.063
Job hours						0.021	0.063	−0.001	0.042
Model constant		27.672	0.000	27.301	28.044	30.794	0.000	28.014	33.575
Total observations, N		464				464			

Table 6.6

Female: Regression of Job Strain Counts on BMI at Wave Four with the Removal of Three Outliers

Female		Model A				Model B			
		B	P		CI95	B	P		CI95
Job strain	0	Reference							
	1	0.267	0.412	−0.372	0.906	0.193	0.549	−0.440	0.826
	2	0.451	0.285	−0.376	1.278	0.384	0.354	−0.428	1.196
	3/4	0.251	0.640	−0.802	1.304	0.100	0.852	−0.950	1.149
Baseline BMI		0.982	0.000	0.925	1.038	0.930	0.000	0.872	0.988
Smoke	No	Reference							
	Yes					−0.596	0.246	−1.607	0.414
Children	No	Reference							
	Yes					−0.597	0.236	−1.584	0.391
Exercise	0	Reference							
	1					−0.648	0.041	−1.270	−0.027
	2					−1.073	0.004	−1.798	−0.347
Finance probs	No	Reference							
	Yes					0.223	0.616	−0.649	1.095
RAND-MHC						0.020	0.300	−0.018	0.058
RAND-PHC						−0.066	0.000	−0.103	−0.030
Education						−0.055	0.390	−0.182	0.071
Job hours						0.020	0.067	−0.001	0.042
Model constant		27.660	0.000	27.293	28.028	30.589	0.000	27.816	33.362
Total observations, N		461				461			

Note. The three outliers were removed from the 3/4 counts of job strain group.

6.6.3 Modelling the Results of an Interaction of Job Strain Accumulation with Baseline BMI on BMI at Wave Four

The interaction between baseline BMI and counts of job strain, on BMI at wave four were analysed in linear regression analyses. In males (see Table 6.7), unadjusted model A showed that the association between later BMI and one report of job strain, compared to males who had never reported job strain, was dependent on baseline BMI (but there was no significant interaction with baseline BMI for males who reported two, or three or four counts of job strain). With covariates modelled (model B), compared to those who had never reported job strain, only those males who had experienced one episode of job strain had a different association with BMI at wave four that was dependent on baseline BMI. There was a negative relationship with BMI at wave four, and a visual inspection of the slopes representing each count of job strain (see Figure 6.1) suggests that those whose baseline BMI was higher than average and who reported one count of job strain had lower subsequent BMIs than those with similar baseline BMIs at wave one who never reported job strain.

For further context, an examination of the marginal means of BMI at wave four (see Table 6.8) demonstrates that males whose BMI at baseline was four BMI points above average and who experienced one count of job strain had significantly lower BMIs at wave four than males who had never experienced job strain. Conversely, those whose BMI was eight points below average and who experienced one count of job strain were observed to have BMIs at wave four that were significantly higher than those of their male counterparts who had never experienced job strain.

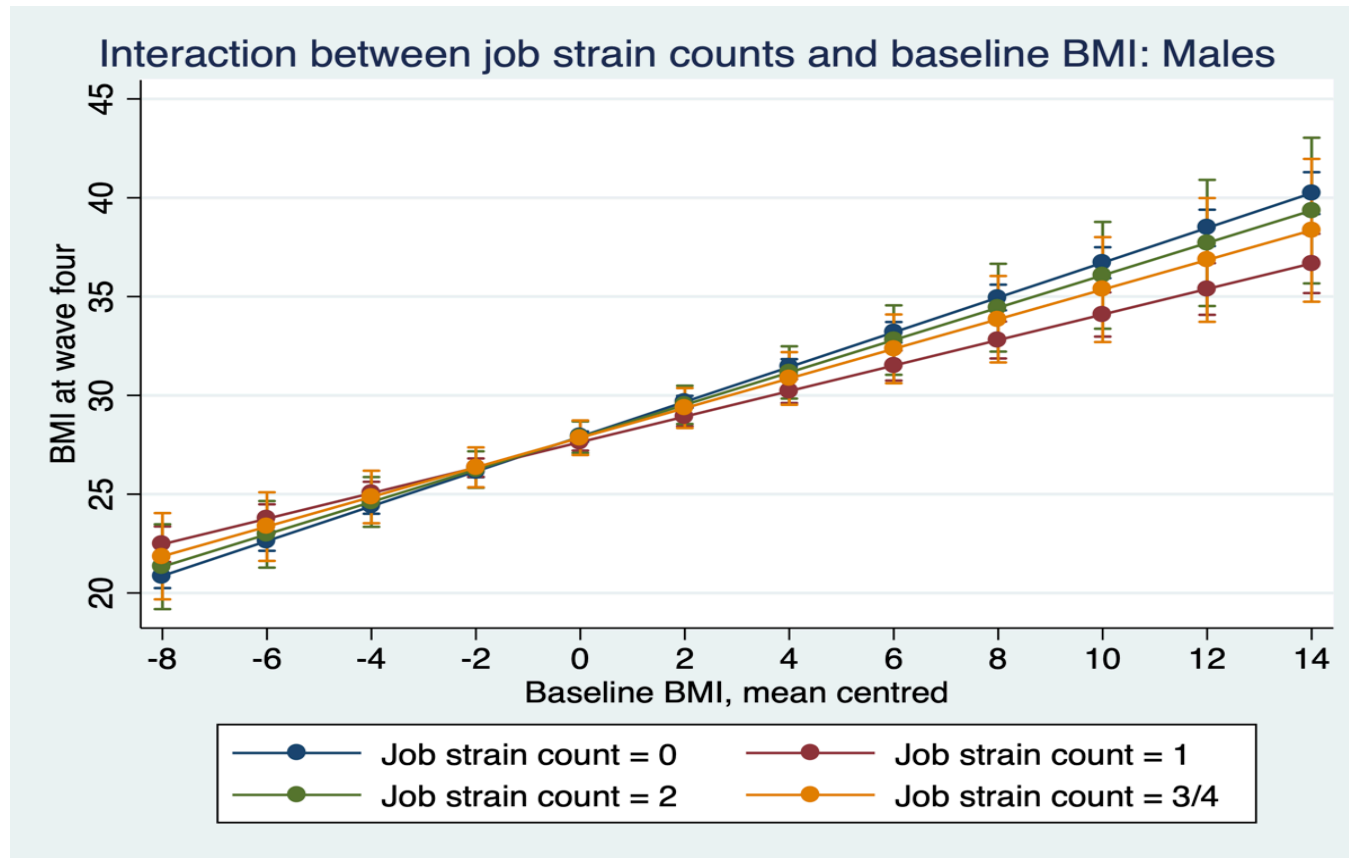
Table 6.7

Male: Regression of Job Strain Counts on BMI at Wave Four (Baseline BMI Included), Including Interaction of Baseline BMI and Number of Job Strain Counts

Male		Model A				Model B			
		B	P		CI95	B	P		CI95
Job strain	0	Reference							
	1	−0.238	0.360	−0.749	0.272	−0.277	0.281	−0.782	0.228
	2	0.140	0.745	−0.704	0.983	−0.028	0.948	−0.873	0.817
	3/4	0.086	0.856	−0.841	1.012	−0.054	0.908	−0.971	0.863
Baseline BMI		0.925	0.000	0.853	0.996	0.880	0.000	0.808	0.953
JS*BaseBMI	0								
	1	−0.268	0.000	−0.392	−0.143	−0.234	0.000	−0.358	−0.111
	2	−0.119	0.384	−0.388	0.150	−0.061	0.651	−0.326	0.204
	3/4	−0.092	0.491	−0.356	0.171	−0.131	0.322	−0.390	0.128
Smoke	No	Reference							
	Yes					−0.619	0.149	−1.462	0.223
Children	No	Reference							
	Yes					0.010	0.976	−0.669	0.689
Exercise	0	Reference							
	1					0.025	0.927	−0.510	0.560
	2					−0.562	0.055	−1.137	0.012
Finance probs	No	Reference							
	Yes					−0.200	0.573	−0.897	0.497
RAND-MHC						0.010	0.481	−0.018	0.038
RAND-PHC						−0.044	0.011	−0.077	−0.010
Education						−0.124	0.015	−0.224	−0.024
Job hours						0.028	0.003	0.010	0.047
Model constant		27.890	0.000	27.623	28.157	30.496	0.000	28.178	32.814
Total observations, N		525				525			

Figure 6.1

The Interaction Between Baseline BMI (at Wave One) and the Number of Job Strain Counts on Males' BMI at Wave Four, After Adjustment for Covariates



Note. The average BMI at wave four was 27.66; the bars around each circle indicate the 95% confidence interval around the estimate. Baseline BMI was centred (0) at 26.87.

Table 6.8

Marginal Means (M. Mean) for Males' BMI at Wave Four According to Baseline BMI at Wave One and Accumulation of Job Strain

Baseline BMI	Job strain count	M. mean for wave 4 BMI	P	CI95	
18.8	0	20.870	0.000	20.247	21.493
	1	22.468	0.000	21.569	23.367*
	2	21.330	0.000	19.184	23.476
	3/4	21.861	0.000	19.678	24.043
20.8	0	22.630	0.000	22.135	23.126
	1	23.760	0.000	23.033	24.486
	2	22.968	0.000	21.284	24.653
	3/4	23.360	0.000	21.624	25.096
22.8	0	24.391	0.000	24.010	24.771
	1	25.051	0.000	24.476	25.627
	2	24.607	0.000	23.347	25.867
	3/4	24.859	0.000	23.531	26.187
24.8	0	26.151	0.000	25.858	26.445
	1	26.343	0.000	25.878	26.808
	2	26.245	0.000	25.322	27.169
	3/4	26.358	0.000	25.351	27.366
26.8 (0 centre)	0	27.912	0.000	27.649	28.175
	1	27.635	0.000	27.207	28.063
	2	27.884	0.000	27.086	28.681
	3/4	27.858	0.000	26.981	28.734
28.8	0	29.672	0.000	29.365	29.979
	1	28.927	0.000	28.444	29.409
	2	29.522	0.000	28.555	30.489
	3/4	29.357	0.000	28.347	30.368
30.8	0	31.433	0.000	31.031	31.834
	1	30.218	0.000	29.615	30.822*
	2	31.161	0.000	29.837	32.484
	3/4	30.856	0.000	29.524	32.189
32.8	0	33.193	0.000	32.674	33.713
	1	31.510	0.000	30.750	32.270*
	2	32.799	0.000	31.043	34.555
	3/4	32.356	0.000	30.615	34.096
34.8	0	34.954	0.000	34.305	35.602
	1	32.802	0.000	31.867	33.736*
	2	34.437	0.000	32.216	36.659
	3/4	33.855	0.000	31.667	36.042
36.8	0	36.714	0.000	35.931	37.498
	1	34.094	0.000	32.975	35.212*
	2	36.076	0.000	33.373	38.778
	3/4	35.354	0.000	32.701	38.008

Note. * = no overlap in 95% confidence interval with 0 counts of job strain.

For females, in univariate model A, the interaction term was observed to have a significant relationship with BMI at wave four for two, and three and four combined counts of job strain. In multivariate model B, three or four counts of job strain significantly interacted with baseline BMI, although the significance of the interaction for two counts of job strain was attenuated ($p=.057$). Further, the direction of the relationship for each count contrasted each other: a negative relationship for those who had experienced two counts of job strain, and a positive relationship with increased wave four BMI for those who had experienced three or four counts of job strain. Experiencing one count of job strain was not significantly different from those who had never reported job strain in either model. In the unadjusted model A, three or four counts of job strain also demonstrated a significant main effect on BMI at wave four, although this was attenuated in the fully adjusted model (model B).

The analyses with the three identified outliers removed (see Table 6.10) revealed a different pattern of results for three or four counts of job strain, showing that the main and interaction estimates for three or four counts of job strain were not significant in model A or model B. The removal of the three outliers also attenuated the magnitude of the estimates in each model, such that they were comparable with the size of the estimates for one count of job strain. In these analyses, no counts of job strain were significantly different from those who had never experienced job strain.

Reflecting the insignificance reported in the analyses, at all estimated values above and below the average baseline BMI, the confidence intervals for one, two, and three or four counts of job strain overlapped with the estimated marginal means for females who had never experienced job strain (as seen in Table 6.11).

An observation of the standard errors for the marginal means of BMI at wave four, as predicted for each count of job strain at specified values of baseline BMI, reported a general

pattern of increasing error size as baseline BMI moved further from the average in the analyses of both males and females (above and below the average). Further, the standard errors for two, and three or four counts of job strain were consistently double the size of the standard errors for those who reported zero and one count of job strain. This was likely due, at least in part, to the decreased sample sizes in these categories. In females, increases in the size of the standard error by job strain count were not as dramatic as those for males, although they became more pronounced in the extremes of baseline BMI (e.g., 10 points above average BMI), reflecting the pattern as observed in males.

Table 6.9

Female: Regression of Job Strain Counts on BMI at Wave Four (Baseline BMI Included), Including Interaction of Baseline BMI and Number of Job Strain Counts

Female		Model A				Model B			
		B	P		CI95	B	P		CI95
Job strain	0	Reference				Reference			
	1	0.293	0.369	−0.348	0.935	0.225	0.485	−0.407	0.857
	2	0.339	0.422	−0.491	1.170	0.273	0.510	−0.540	1.087
	3/4	1.029	0.050	0.001	2.057	0.739	0.158	−0.287	1.765
Baseline BMI		0.992	0.000	0.921	1.063	0.922	0.000	0.849	0.995
JS*BaseBMI	0	Reference				Reference			
	1	0.061	0.398	−0.081	0.203	0.111	0.123	−0.030	0.251
	2	−0.194	0.027	−0.366	−0.023	−0.166	0.057	−0.337	0.005
	3/4	0.350	0.004	0.110	0.589	0.316	0.008	0.081	0.550
Smoke	No	Reference				Reference			
	Yes					−0.651	0.204	−1.655	0.354
Children	No	Reference				Reference			
	Yes					−0.440	0.378	−1.419	0.540
Exercise	0	Reference				Reference			
	1					−0.594	0.061	−1.217	0.028
	2					−1.030	0.005	−1.753	−0.308
Finance probs	No	Reference				Reference			
	Yes					0.269	0.541	−0.595	1.132
RAND-MHC						0.023	0.232	−0.015	0.060
RAND-PHC						−0.074	0.000	−0.110	−0.037
Education						−0.076	0.237	−0.203	0.050
Job hours						0.021	0.052	0.000	0.043
Model constant		27.667	0.000	27.300	28.034	31.051	0.000	28.275	33.826
Total observations, N		464				464			

Table 6.10

Female: Regression of Job Strain Counts on BMI at Wave Four (Baseline BMI Included), Including Interaction of Baseline BMI and Number of Job Strain Counts with the Removal of Three Outliers

Female		Model A				Model B			
		B	P		CI95	B	P		CI95
Job strain	0	Reference				Reference			
	1	0.293	0.369	−0.347	0.934	0.229	0.478	−0.404	0.862
	2	0.339	0.422	−0.490	1.169	0.274	0.509	−0.541	1.088
	3/4	0.428	0.493	−0.796	1.651	0.322	0.606	−0.905	1.549
Baseline BMI		0.992	0.000	0.921	1.063	0.923	0.000	0.850	0.997
JS*BaseBMI	0	Reference				Reference			
	1	0.061	0.397	−0.081	0.203	0.110	0.127	−0.031	0.251
	2	−0.194	0.026	−0.366	−0.023	−0.166	0.057	−0.337	0.005
	3/4	0.095	0.613	−0.273	0.463	0.141	0.444	−0.220	0.501
Smoke	No	Reference				Reference			
	Yes					−0.632	0.217	−1.638	0.374
Children	No	Reference				Reference			
	Yes					−0.473	0.350	−1.467	0.521
Exercise	0	Reference				Reference			
	1					−0.574	0.071	−1.199	0.050
	2					−1.004	0.007	−1.729	−0.278
Finance probs	No	Reference				Reference			
	Yes					0.240	0.588	−0.630	1.111
RAND-MHC						0.020	0.303	−0.018	0.057
RAND-PHC						−0.071	0.000	−0.107	−0.034
Education						−0.074	0.256	−0.201	0.054
Job hours						0.021	0.050	0.000	0.043
Model constant		27.667	0.000	27.300	28.034	30.991	0.000	28.204	33.778
Total observations, N		461				461			

Note. The three outliers were removed from the 3/4 counts of job strain group.

Table 6.11

Marginal Means (Model B) for Females' BMI at Wave Four According to Baseline BMI at Wave One and Accumulation of Job Strain with Three Outliers Removed

Baseline BMI	Job strain count	M. mean for wave 4 BMI	P	CI95	
19.5	0	22.128	0.000	21.593	22.662
	1	21.699	0.000	20.858	22.539
	2	23.397	0.000	22.291	24.504
	3/4	21.606	0.000	19.836	23.376
21.5	0	23.975	0.000	23.538	24.411
	1	23.765	0.000	23.099	24.431
	2	24.912	0.000	24.018	25.806
	3/4	23.734	0.000	22.493	24.975
23.5	0	25.822	0.000	25.450	26.194
	1	25.831	0.000	25.286	26.376
	2	26.427	0.000	25.674	27.180
	3/4	25.862	0.000	24.887	26.838
25.5 (0 centre)	0	27.668	0.000	27.309	28.028
	1	27.897	0.000	27.379	28.415
	2	27.942	0.000	27.215	28.669
	3/4	27.991	0.000	26.823	29.159
27.5	0	29.515	0.000	29.113	29.918
	1	29.963	0.000	29.367	30.560
	2	29.457	0.000	28.630	30.284
	3/4	30.119	0.000	28.451	31.786
29.5	0	31.362	0.000	30.874	31.850
	1	32.030	0.000	31.280	32.779
	2	30.972	0.000	29.955	31.988
	3/4	32.247	0.000	29.967	34.527
31.5	0	33.209	0.000	32.612	33.807
	1	34.096	0.000	33.156	35.036
	2	32.487	0.000	31.231	33.742
	3/4	34.375	0.000	31.439	37.312
33.5	0	35.056	0.000	34.336	35.776
	1	36.162	0.000	35.012	37.313
	2	34.002	0.000	32.481	35.522
	3/4	36.504	0.000	32.892	40.116
35.5	0	36.903	0.000	36.053	37.753
	1	38.228	0.000	36.857	39.600
	2	35.517	0.000	33.716	37.317
	3/4	38.632	0.000	34.334	42.930

Note. * = no overlap in 95% confidence interval for 0 counts of job strain.

6.7 Discussion

This chapter examined whether individuals who accumulated job strain over the study period had differences in BMI at the conclusion of the study period compared with those who never reported experiencing job strain. In doing so, the analyses explored whether there was evidence for a dose-response association between the number of counts of job strain experienced and BMI (or an alternative pattern of cumulative effects). The second aim of this chapter was to consider evidence for whether baseline BMI (being higher or lower than average BMI at the beginning of the study) may influence an association between an accumulation of job strain and BMI at the conclusion of the study. The results showed no evidence for a cumulative pattern of experiencing multiple counts of job strain with higher or lower BMI outcomes at the end of the study, and there was no evidence that this finding changed contingent upon higher or lower baseline BMI.

6.7.1 Discussing the Absence of the Main Effects for Job Strain Accumulation

The first set of analyses investigated whether cumulative counts of job strain were associated with BMI at the conclusion of the study for both males and females, with no relationship found for either sex. The lack of any main effects is a result disparate from the significant trend reported by Brunner et al. (2007), which was the only other study to analyse an accumulation of four measurements of job strain. The authors concluded strong evidence for a causal dose-response effect of increasing counts of job strain on increased BMI—in particular, for crossing the obese BMI threshold of 30. The trend for increasing counts of job strain was significantly associated with increased risk for obesity for both sexes when combined together in analyses, even when fully adjusted for covariates that might otherwise explain this relationship.

6.7.1.1 Results for Females

While Brunner et al. (2007) did not find a significant dose-response trend for females' increased risk for obesity after 19 years, they found that three or four counts of job strain was associated with obese BMIs for females in unadjusted models. However, this finding became nonsignificant with adjustment for other covariates, bringing it more in line with the null findings here using the PATH Through Life dataset. While not significant in the present findings, the predictions for females showed a pattern of increasing estimates with each count of job strain ($B=.182$ for one count of job strain, $.370$ for two counts, and $.493$ for three or four counts in model B). Despite the nonsignificance in the results, it is worth highlighting the effect that the removal of just three outliers had in altering this finding, adjusting the estimate for three or four counts for job strain to less than just one count ($B=.193$ for one count of job strain, $.384$ for two counts, and $.100$ for three or four counts). These outliers were not removed from the analysis because further investigations showed that, while they were only slightly higher on baseline BMI, they were vastly higher on follow-up BMI. While the data were clearly unusual, that they experienced chronic job strain (three or four counts) may speak to the validity of an association of chronic job strain with their higher follow-up BMI and is worthy of further investigation in future research.

6.7.1.2 Results for Males

The results for males, finding no cumulative association or any main effects of job strain counts with BMI at follow-up, are also disparate from those reported by Brunner et al. (2007). For males, Brunner et al. found both a significant dose-response trend for increasing counts of job strain, and independently of the trend analysed, they found that two and three or four counts of job strain were associated with increased odds of obesity. Thus, the current results for males are instead in line with the null findings reported by Eek and Östergren (2009), Ishizaki et al. (2008), and Nyberg et al. (2012).

In the absence of cumulative effects for males and females, the current study is in agreement with the conclusions of Ishizaki et al. (2008) and Nyberg et al. (2012) that evidence for a cumulative or dose-response relationship is lacking. In contrasting the present null results and those of these past studies with the results of Brunner et al. (2007), there are several differences to be considered. First, Brunner et al. operationalised job strain using an iso-strain measure, which categorises job strain by taking into account perceptions of social support in addition to job demands and control. Brunner et al. analysed each component of job strain individually for their association with obesity in unadjusted models, finding that high job demands and low job control alone were not significantly associated with obesity. However, in unadjusted bivariate analyses, perceptions of low social support were significantly associated with obesity such that the trend for increased counts of perceived low social support was significant in predicting obesity for males, and for females when tested separately. Thus, the addition of social support to categorise job strain may have enabled their measure to be more sensitive. This may have been influential in the discrepancy between the results of those who operationalised job strain based on the JCQ, such as the present study, in comparison with the iso-strain method.

However, this does not explain the discrepancy between the current null findings and the findings of other studies that found evidence that an accumulation of job strain was associated with increased BMI. Fujishiro et al. (2015), Eek and Östergren (2009), Niskanen (2016), and Klingberg et al. (2019), who all found evidence for a relationship of persistent job strain with increased BMI, measured job strain using the JCQ or a close variant, with no additional social support component.

A further difference between the present study and that of Brunner et al. (2007) is the outcome measure. The present study analysed average variations in BMI as a function of cumulative job strain counts, while the latter study specifically focused on BMIs that had

increased above the obese threshold of 30. As a result, different analysis methods were more suitable for each study, with Brunner et al. using logistic regression to model odds ratios based on their binary outcome variable (whether participants had a BMI of over 30 or not at the conclusion of their study). In the present study, BMI was modelled as a continuous outcome (allowing the testing of finer variations in BMI on a continuum). However, this additional factor still does not explain the discrepant findings of other studies that also modelled continuous average change in BMI (i.e., Eek & Östergren, 2009; Fujishiro et al., 2015). Thus, despite analytical modelling differences, the findings here suggest that no association of an accumulation of job strain with BMI is present, although inconsistencies remain within the literature.

The reasonable conclusion from these first sets of analyses is that there is no evidence in the current study to support a dose-response, or more general accumulative, association of job strain on BMI. Although these null results are somewhat in agreement with others regarding the absence of an accumulative association (i.e., Ishizaki et al., 2008; Nyberg et al., 2012), they are also simultaneously inconsistent with the findings of others (i.e., Brunner et al., 2007; Eek & Östergren, 2009; Fujishiro et al., 2015; Klingberg et al., 2019; Niskanen, 2016). While the findings of the current study contribute to the small body of literature that is available, the inconsistency that is present requires further research to add clarity.

6.7.2 Discussion of Findings for an Interaction

The present study appears to be the first to explicitly examine an interactive effect of job strain accumulation with baseline BMI using more than two measurements of job strain. However, there was no evidence to suggest that baseline BMI is an important consideration in an association between an accumulation of job strain and BMI. Although the results were different depending on the count of job strain experienced, there was little cumulative or consistent pattern as job strain counts increased. In the models analysing the interaction

between baseline BMI and the number of job strain counts, two and three or four counts of job strain in combination with baseline BMI had a significant relationship with BMI at wave four for females. However, the relationship between baseline BMI and job strain was indicated to be opposite for each of these counts: a negative relationship for females reporting two counts of job strain, and a positive relationship for those reporting three or four counts. However, a comparison of the analyses with and without the inclusion of the three identified outliers showed that the significance of the interaction between baseline BMI and three or four counts of job strain was driven by the three outliers. As highlighted above, while this presents a possible basis for further investigations, the results here broadly imply that there is no robust evidence for an accumulation of job strain counts with BMI, and that this is not dependent on baseline BMI.

In unadjusted models for females in the present results, those with a higher-than-average BMI at baseline who experienced two counts of job strain had significantly lower BMI at follow-up. While this finding was largely attenuated when accounting for other variables, it is interesting to note that the estimates for females reporting job strain twice in the results of Brunner et al. (2007) also consistently demonstrated the lowest odds for obesity, although this finding was not dependent on baseline BMI in their results. For example, in their analyses, the odds for obesity for those females who experienced one count of job strain ranged from 1.23 to 1.18 (the range being dependent on adjustment for differing covariates), and from 2.02 to 1.92 for those who had experienced job strain three or four times. But for those females reporting job strain twice, the odds were far lower, ranging from .79 to .64. While this finding was not significant in Brunner et al., and was only significant in unadjusted models here, it is interesting to note this consistency among both studies with four measurements of job strain. Of course, this presents a further inconsistency with the results of other studies that found a significant positive relationship between two counts of job strain in

those with higher-than-average BMI at baseline and increased BMI at follow-up for females (Fujishiro et al., 2015; Klingberg et al., 2019; Niskanen et al., 2017).

For males, there was a significant negative interaction between one experience of job strain (v. none) and BMI at baseline, predicting BMI at wave four. This indicated that, for males whose BMI began above average at wave one and who experienced job strain once, their BMI was significantly lower at the conclusion of the study. This was the case when compared to males who never reported job strain, whose BMI increased to a lesser extent. Experiencing job strain significantly decreased the average increase observed in BMI (across all males). Simultaneously, for males whose BMI was below average at baseline and who had just one experience of job strain, the increase in their average BMI was greater than for those who had not experienced job strain. In contrast, no significant interactions were observed for two and three or four counts of job strain with follow-up BMI. Thus, it appears that while one count of job strain may interact with baseline BMI, there was no evidence for any linear or cumulative increase of association between more counts of job strain with BMI, and that this was moderated by BMI at baseline.

Regarding BMI increase, while one count of job strain led to an apparent protective factor for males with higher-than-average BMI at baseline, it was a risk factor for males with lower-than-average BMI at baseline. However, the confidence intervals of the predicted marginal means warrant caution against any over-interpretation of the evidence present in this study (see Table 6.8). The trajectories (see Figure 6.1) and predicted estimates for never reporting job strain were not statistically dissimilar from reporting two, or three or more, counts of job strain. While the 95% confidence intervals for the predicted marginal means for males who had experienced one count of job strain were significantly different from those for males who had never reported job strain, they overlap with the confidence intervals for both two and three or four counts of job strain at all values of baseline BMI. The overlapping

confidence intervals and the lack of significant findings for more than one count limits the confidence in drawing distinctions between different counts of job strain and not experiencing job strain.

Further, the negative association reported here for males with above-average BMI at baseline is discrepant from the findings of Brunner et al. (2007). Despite not testing an interaction with baseline BMI, Brunner et al. found an accumulation of job strain counts to be associated with BMI increase above 30 (incident obesity). In contrast, the present results show the opposite pattern: namely, an association of one count of job strain only with a decrease in males' BMI. This finding is consistent with that reported by Nyberg et al. (2012). The results of longitudinal analyses reported by Nyberg et al. found that job strain at follow-up, but not baseline (thus, only one count of job strain), was associated with both increased and decreased BMI. However, a direct comparison of these results is limited because the analyses of Nyberg et al. were not sex-specific; rather, sex was controlled for as a covariate in the analyses.

The only other findings similar to the present study are those of Niskanen et al. (2017). While the evidence from Niskanen et al. regarding job strain does not support the findings here (they reported null results when stratified by baseline BMI), Niskanen et al. also tested job demands and control and reported a significantly increased likelihood of major weight gain (293% increase) for males who reported one count of increased job demands and were overweight and obese at baseline. For males who were normal weight at baseline, Niskanen et al. additionally reported a 411% increased risk of major weight gain if job demands decreased over time (from high demands at baseline to low job demands at follow-up). While these results provide some evidence for an interaction of baseline BMI with changing job demands among males, it is difficult to contrast them directly with the current results because of the sole focus on job strain and only two time points. However, it appears

that just one count of high job demands was a defining factor for both of their significant results.

6.7.3 Limitations

The results presented in this chapter contribute to a limited body of literature examining the risk of job strain accumulation for future BMI outcomes. The analyses are original in testing an interaction between baseline BMI and job strain accumulation on later BMI outcomes using more than two measurements of job strain. Given this, the broadest limitation is the need for further studies and testing to establish a reliable body of evidence. Another notable limitation surrounds the population sample analysed. Similar to Brunner et al. (2007), a complete cases sample was used in the analysis, whereby those who dropped out at, or missed, any wave of data collection were excluded from the analysis, which may have resulted in bias. Typically, those who remain active within longitudinal studies are able to do so because they have greater resources and fewer stresses to manage in their lives (Teague et al., 2018), causing bias within the sample. In this study, analysis of the characteristic differences between those who dropped out or missed responding to key variables at any wave and the complete cases sample analysed here showed minimal differences for important variables such as the final wave four BMI and BMI at baseline. However, the possibility remains that the analysis of an employed sample in their mid-life may already reflects bias, because the individuals who experienced the deleterious effects of job strain may not have participated in the study in the baseline sample.

The high socioeconomic profile of Canberra and the surrounding regions from which the PATH dataset was drawn may further limit the generalisability of the present results (Anstey et al., 2020). This is because average BMI generally declines with increased SES (Hayes et al., 2015). The high SES profile of Canberra and the surrounding regions may further bias the representation of individuals experiencing job strain, because there may be

fewer individuals employed in the stressful conditions sampled. This combination of factors would likely result in an underestimation of the size of an association between baseline BMI and counts of job strain.

In studies with more than two data points, an accumulation of counts may not always be consecutive. This may be an important consideration, because consecutive or chronic (or persistent) experiences of job strain may have different associations with BMI, although this has not been explicitly tested to date. Presently, the studies that have explicitly examined accumulation—namely, this chapter and Brunner et al. (2007)—have investigated the total accumulation of job strain over a duration without an indication of consecutive counts. However, at the highest count of job strain, accumulation may converge with consecutive reports to represent the same thing. For example, in the present study, for which information on job strain was collected at each wave, the maximal counts of job strain by default indicate some consecutive reports of job strain. Brunner et al. (2007) also had a maximal count of four job strain reports. However, the Whitehall study had seven waves of data collection, and data on job strain were only collected at four time points, leaving non-uniform periods between the sampling of job strain. Thus, focusing on the total number of counts of job strain over the study duration was a sensible alternative.

Further, while job strain may be reported at each consecutive wave of data collection, doubts remain regarding what each job strain report actually indicates: Does each consecutive report indicate a chronic continuation of job strain from a prior wave, or a separate discrete experience? Given the long time-span between the measurements of job strain in both Brunner et al. (2007) and the present study, neither is able to accurately indicate whether the job strain experiences occurred persistently. Large epidemiological studies often have years between data collection waves; without more sensitive data collection, any discussion regarding a continuous chronic experience cannot be strongly substantiated.

An obvious limitation is the small sample size. Representing the prolific nature of job strain, almost half of females and just over one-third of males who were sampled reported experiencing job strain at least once throughout the 12-year period. However, only 67 males and 97 females reported job strain more than once. The overall sample size and the cell sizes of the corresponding categories were relatively small when considered within the context of epidemiological research and its purposes for generalising to populations. However, compared with past research, the cell sizes in the current study were larger than those of Brunner et al. (2007), who analysed just 20 males and seven females reporting three or four experiences of job strain across their study. Despite the larger cell size in the current study, the generalisability of the results must be considered cautiously given these limitations, which are further compounded when considering the bias introduced by complete cases analysis and the atypical SES profile of Canberra and the surrounding regions from which the sample was obtained.

6.8 Conclusions

This study aimed to examine whether an accumulation of job strain across a 12-year period was associated with subsequent BMI, and whether this association may be dependent on BMI at baseline. The study aimed to assess evidence for a dose-response association between increasing counts of job strain with a pattern of response in BMI over the study period. No indication of an accumulation of job strain on future BMI was found for males or females, and only limited evidence was found supporting that baseline BMI may moderate a relationship between one count of job strain with later BMI outcomes for males.

Regarding a dose-response effect, there was no robust evidence of an association. Despite this, for males whose BMI was higher than average and who experienced job strain once, there appeared to be some evidence of a differential association with BMI outcomes—specifically, that if males experienced job strain once BMI decreased given higher-than-

average BMI at baseline, and conversely, BMI increased given lower than average baseline BMI. While this result is inconsistent with an accumulation between job strain and BMI outcomes, this finding could be explored in further research.

It is an important finding in and of itself that there was no main effect for the accumulation of job strain, including for individuals who reported three or four counts of job strain—that is, those who reported high strain at every, or almost every, wave of data collection. The null findings here, combined with the weight of the evidence in other chapters in this thesis, suggest that there is no direct association between job strain and BMI.

Chapter 7: General Discussion and Conclusion

7.1 Overview of Thesis Aims and Structure

The broad overarching aim of this thesis was to contribute knowledge on whether there is an association between job strain and BMI. This broad aim was explored in each of the chapter-specific aims and analyses conducted, though in differing ways, using population-based representative data from the PATH Through Life study (predominantly the midlife 40s cohort). This final summary chapter begins by re-visiting each of the thesis chapters and recalling the critical review of the existing literature, and how this informed the arguments, research questions and analyses within each chapter.

The context for the research in this thesis was described in the introductory chapter, including descriptions and evidence for the growing prevalence and health impacts of work stress, particularly within Australia (Safe Work Australia, 2019; Black Dog Institute, 2021; Medibank & KPMG, 2008). The importance of looking at BMI specifically as a health outcome related to work stress is underscored by the impact of increasing BMI and overweight and obesity, globally and in the Australian population (Di Cesare et al., 2016; Hayes et al., 2015; Hayes et al., 2019; Ng et al., 2014). Job strain was selected as the focal measure of work stress for investigation, given its widespread use in the literature and both theoretical and empirical support for its associations with health risk and disease (Amiri & Behnezhad, 2020; Guan et al., 2017; Hanson et al., 2018; Kuper & Marmot, 2003; Miranti & Li, 2020). However, the findings specifically examining job strain in relation to BMI (including overweight and obesity) are inconsistent (Azagba & Sharaf, 2012; Fujishiro et al., 2015; Kivimäki et al., 2006; Kouvonen et al., 2005; Nyberg et al., 2012), and thus, the introductory chapter served to lay a theoretical and evidence-informed foundation for how and why job strain may be associated with BMI.

The rationale for an association between job strain and BMI includes understanding that there are complex (but established) links between stress more generally, health behaviours, biological pathways, and disease (with BMI, overweight and obesity, playing a role in disease development) (Brunner, 2006; McEwen, 2006; Siegrist, 2006; Suvarna et al., 2020; Thoits, 2010)). There are also several factors associated with both job strain and BMI that strengthen the rationale for a possible relationship, such as fatigue (Bültmann et al., 2002; De Lange et al., 2009; Guan et al., 2017; Resnick et al., 2006; Sonnentag & Jelden, 2009), and mental and physical health (Burns et al., 2016; McTernan et al., 2013; Mikolajczyk et al., 2009; Thurber et al., 2018). The introduction concluded that there was certainly theoretical and empirical support to expect a relationship between job strain and BMI, and outlined the research questions to be answered by the thesis and how, in the analyses chapters, these questions would be explored.

Building on the broad literature review in the introductory chapter, more detailed reviews of studies examining job strain and BMI were provided within each chapter, in advance of the analyses, so nuanced evidence could be highlighted as necessary and relevant. This was important to demonstrate that the inconsistencies amongst prior findings may have been due to heterogeneity in study methods and analyses. Some empirical studies were re-appraised and featured across analyses chapters where relevant to understanding the focus of that specific chapter. For example, Nyberg et al. (2012) examined a cross-sectional and longitudinal relationship within the same paper, returning varying evidence in each set of analyses, and so this paper features in both cross-sectional and longitudinal chapters.

Turning specifically to the first analysis chapter - Chapter 3, reviewed the cross-sectional literature on job strain and BMI. The chapter begins by evaluating the evidence from one of the earliest reviews on job strain and BMI (by Overgaard et al., 2004), which was largely unsupportive of an association. However, further studies post the review by

Overgaard, Gyntelberg, and Heitmann (2004) suggest a mixed state of findings, supporting further investigation (Azagba & Sharaf, 2012; Brunner et al., 2007; Fernandez et al., 2010; Fujishiro et al., 2015; Kivimäki et al., 2015). The possibility that these mixed findings are in part because of varied operationalisations of BMI as either a continuous or categorical measure was discussed, with the conclusion that parallel analyses (testing the BMI measure both continuously and categorically) would be beneficial. Given this, the aim of the first set of analyses was to extend upon the prior cross-sectional literature and investigate whether the results may be replicated or attenuated, depending upon the use of categorical and continuous BMI variables. A lack of past relevant Australian studies was also highlighted, in particular that there were no published studies modelling job strain in association with overweight or obesity (i.e., categorically), and also few Australian studies looking at psychosocial job quality more broadly and BMI. As such, it was a further aim to expand the available research examining job strain and BMI specifically in Australia. A review of these findings is described below in section 7.2.1.

Some studies have examined evidence for a relationship between job strain and BMI using longitudinal data to try and establish evidence for a causal association. However, this body of literature is small, and thus there are calls for further longitudinal studies (e.g., Azagba & Sharaf, 2012; Klingberg et al., 2019; Bean, 2017). Whilst the evidence from longitudinal data is often considered more robust than that from cross-sectional analyses, there are still inconsistencies amongst the longitudinal findings reported. A critical appraisal of the available studies in Chapter 4 identified conceptual and analytic issues to be addressed: specifically, the examination of more modest BMI variation over time, the use of appropriate longitudinal analytic techniques, the importance of the length of follow-up, the importance of multiple data points to examine changes over time (i.e., more than one change cycle), and the stratification of analyses by sex. Aligning with this, the core aim of the longitudinal chapter

(Chapter 4) was to use the PATH dataset to design and test four different models that explored the possibility of a relationship between job strain and BMI over time, and in doing so, address these conceptual and analytic issues. The results for each of the four multi-level models exploring the relationship of job strain with BMI over time for each sex are summarised in section 7.2.2.

Reviewing the longitudinal literature, it became apparent that some studies had controlled for baseline BMI in analyses, or had stratified analyses by baseline BMI categories, or even tested an interaction of job strain with baseline BMI. Though the findings of such studies were also inconsistent, they raise the possibility that job strain may be associated with BMI differentially dependent upon whether an individual's BMI is higher or lower at the beginning of a study. In the longitudinal chapter (Chapter 4), the issue of individual variation in BMI over the life course was discussed alongside the ability of longitudinal models to explore such variance. The analyses in Chapter 5 extended this rationale to variation in baseline/initial BMI, following the results of past studies suggesting that the relationship of job strain and BMI may vary systematically with higher or lower BMI at baseline. The four longitudinal models designed in Chapter 4 were re-tested in Chapter 5 with the inclusion of an interaction term between job strain and baseline BMI modelled continuously. In line with some of the prior studies, the four longitudinal models were also retested stratified by baseline BMI categories. This dual approach provided a more comprehensive set of results than previously available in the literature, which are discussed in Section 7.2.3.

Finally, the literature also shows some prior evidence that the nature of a relationship between job strain and BMI may be cumulative over time, or even follow a dose-response pattern (i.e., Brunner et al., 2007; Klingberg et al., 2019). However, given most prior studies have one or two measurements of job strain, overall the literature is limited in its ability to

answer this question, suggesting further exploration is needed. The PATH dataset, with four measurements of job strain over a 12-year follow up period, was strongly placed for such an examination. Thus, the main aim of Chapter 6 was to investigate whether there was evidence for an accumulation of job strain counts over time predicting subsequent BMI. The accumulation of counts of job strain were also examined in interaction with baseline BMI, building on from the prior analyses in Chapter 5. This was an original contribution to the literature that also served to deepen the comprehensive nature of the investigations undertaken within this thesis. A review of these findings is provided in Section 7.2.4.

This final chapter summarises the findings of each analysis chapter in the order of investigation (Section 7.2). The investigations were designed to build on from one-another, interfolding the broad aims across each. The implications from the findings collectively are also discussed (Section 7.2.5), the strengths and limitations of the thesis are acknowledged (Section 7.3) and recommendations for future research directions are made (Section 7.4). Finally, this program of research is concluded with final reflections on the comprehensive approach taken, the contribution to the Australian literature, and the final summation that despite the theoretical and conceptual evidence that supports hypothesising a connection between job strain and BMI, this thesis provides little evidence of such an association (Section 7.5).

7.2 Contribution to Evidence: General Findings

7.2.1 Contribution of Cross-Sectional Investigations

Most prior research on job strain and BMI, overweight or obesity has been conducted using cross-sectional data, making a cross-sectional investigation a suitable first stepping-stone to contribute further evidence to the literature. Additionally, as described above, there are mixed existing findings, with little consistency between studies that have modelled BMI either continuously or categorically. To address this, in Chapter 3 job strain was modelled in

association with both continuous BMI and categories of BMI (normal weight, overweight and obesity) in parallel analyses stratified by sex. The results showed no evidence for an association in any of the analyses modelling BMI continuously or categorically, for either sex. This null finding contributes to the established body of cross-sectional research and is consistent with results from other published studies that similarly reported no evidence for an association (i.e., Lallukka et al., 2008; Overgaard et al., 2004).

Amongst prior Australian research, this null result aligns with the only other study to have tested job strain with continuous BMI (Ostry et al., 2006). However, this thesis chapter's contribution to understanding job strain and BMI in Australia are somewhat discrepant from other Australian studies. For example, Bean et al. (2015) and Ostry et al. (2006) each reported significant findings for the sub-scales of job strain, job control (specifically skill discretion) and job demands, with continuous BMI (neither tested categorical BMI). These subscales were tested in supplementary analyses in this thesis (job control and job demands were tested in association with both continuous and categorical BMI). While in univariate analyses a positive association of low job control with obesity and continuous (higher) BMI was statistically significant, further analyses controlling for the older age of the 40s cohort accounted for this association. Thus, the broad null findings of the cross-sectional analysis chapter show some differences from the findings of other Australian studies. Despite the null findings, these analyses make an original contribution to the examination of job strain with overweight and obesity (categories) in an Australian population, as an association with BMI categories had not been previously examined.

7.2.2 Contribution of Longitudinal Investigations

Though the findings of the cross-sectional associations showed no association, there were clear contributions to be made to the literature by investigating an association of job strain with BMI longitudinally using the PATH data. The slow developing nature of BMI

over time makes a strong case for the investigation of BMI as a continuous variable over time in association with job strain, allowing for more modest associations to be observed if present. The high degree of individual variation in BMI contributes to the appropriateness of analytic techniques able to incorporate multiple observations over time. In combination with this, a review of the prior longitudinal literature identified further conceptual and analytic areas that analysis of the PATH dataset could contribute knowledge and insight to. Guided by these issues raised in the literature review, four multi-level models were designed and tested stratified by sex (in Chapter 4). Each was related to assessing the evidence for an association of job strain with BMI over time, however the results showed no evidence for an association over time using longitudinal data for either sex across any of the models.

The consistency in findings across each of the models strengthen confidence that there was no evidence for an association of job strain with BMI across the 12-years of follow-up in this thesis. The longitudinal investigations build on the existing literature to date: in addition to the broader fixed and random effects models tested, no other prior studies had tested a possible association between baseline job strain and BMI over time, or a lagged-job strain model (where an association between prior job strain and subsequent BMI at the next wave was tested). The benefit in doing so was to examine possible temporal differences in how an association between job strain and BMI might present (i.e., 12-years of BMI follow-up in the baseline job strain model, and a 4-year lag from an experience of job strain and subsequent BMI in the lagged model). This also appears to be the first time (compared to the published literature) that these longitudinal models have been tested stratified by sex, with earlier studies combining males and females in analysis (Kivimäki et al., 2015; Azagba & Sharaf, 2012) despite evidence suggesting there may be important differences. Thus, the lack of findings in these analyses provide an original contribution to the existing literature.

7.2.3 Contributions from Baseline BMI Investigations

The present program of research also contributes original, comprehensive insights into whether any association between job strain and BMI might be dependent on baseline BMI. While the null findings of the previous cross-sectional and longitudinal chapters provided little confidence of an association (aligning with the findings of some others i.e., Kivimäki et al., 2015; Azagba & Sharaf, 2012), the literature suggests there may be a distinction between analyses that control for baseline BMI in analyses, stratify analyses by baseline BMI, or test an interaction of job strain with baseline BMI, compared to those that do not. Thus, this was an important consideration in thoroughly investigating an association of job strain and BMI over time, as an interaction, if present, may have obscured the relationship.

To address this, in Chapter 5 the four models developed for the longitudinal investigations (in Chapter 4) were remodelled and tested with the inclusion of an interaction term for continuous BMI at baseline, to observe whether this influenced any association between job strain and BMI over time. The results showed that for females, all multi-level models, with the exception of the fixed-effects model, were statistically significant when baseline BMI was included as an interaction term. The exception of a significant finding in the fixed-effects models indicates that changes in job strain over time are not associated with changes in BMI over time (i.e. the covariation of both together) regardless of baseline BMI.

Given the operationalisation of BMI within the literature may contribute to the inconsistency amongst findings, the interaction was re-modelled using the normal weight, overweight, and obese baseline BMI categories. However, the results from these models did not support the significant findings with BMI interacted continuously with job strain. Some prior studies had not tested an interaction analytically, but rather had stratified analyses by baseline BMI category (i.e., Klingberg et al., 2019; Ishizaki et al., 2008; Nyberg et al., 2012).

Accordingly, the four longitudinal models were also re-tested stratified by normal weight, overweight, and obese baseline BMI categories. When tested within each of the baseline BMI categories, no evidence was found for a relationship between job strain with BMI over time. Testing the interaction with categories of BMI alongside these stratified models did not support the earlier findings where there was some indication that baseline BMI (modelled continuously) might be important for females, bringing the findings closer to the lack of association demonstrated in the cross-sectional and longitudinal analyses in Chapters 3 and 4. Thus, while there was some evidence for females that warrants further exploration, overall the evidence from this thesis indicates that baseline BMI may not be an important factor.

These investigations testing a possible moderating effect of baseline BMI make an original contribution to the literature on job strain and BMI. Though interactions have been tested in a few prior studies, they have never been modelled using a continuous BMI measure alongside analyses of a categorical BMI interaction, in addition to the somewhat parallel method of stratifying the analyses by baseline BMI category. Thus, the current thesis contributes further insight into the potential for discrepancies in findings to be due to the operationalisation of BMI (as continuous or categorical). This thesis also responds to recommendations from other researchers that the role of baseline BMI be further explored (Klingberg et al., 2019; Fujishiro et al., 2015), overall, finding little evidence that it plays an important role.

7.2.4 Contributions from Accumulation Investigations

The final set of analyses conducted in Chapter 6 aimed to further the evidence available about whether job strain may accumulate over time to be associated with BMI. To date, evidence and discussion surrounding the possibility that job strain may ‘accumulate’ or intensify with increased impact on BMI has been limited. One prior study had suggested a dose-response relationship of job strain with obesity (E. J. Brunner et al., 2007) and further

insights from studies with a minimum of two measurements of job strain suggested the possibility that as job strain experiences accumulated, an association with BMI may strengthen (though these were not intentionally designed to test accumulation, limiting their contributions) (Eek & Östergren, 2009; Fujishiro et al., 2015; Klingberg et al., 2019).

However, analyses in Chapter 6 using the four measurements of job strain from the PATH Through Life data returned no evidence that this was the case, for males or females. This appears to be only the second study to purposefully investigate whether job strain may accumulate, making a valuable contribution to the literature despite the null findings. Further, whilst the earlier study (E. J. Brunner et al., 2007) reported a dose-response relationship of increasing counts of job strain with obesity and incident obesity, this was the first study to explicitly test whether job strain may accumulate and be associated with BMI at follow-up (not categories of BMI).

The contributions moved beyond this, however, as this thesis also appears to be the first study to test whether accumulation may be dependent upon baseline BMI. Taking guidance from the earlier discussion of baseline BMI with job strain, these analyses provided another opportunity to investigate varying presentations of a relationship between job strain and BMI (as is tied together throughout this thesis): specifically, whether any association between accumulated job strain over time and BMI may be dependent on higher or lower BMI at baseline, and whether increasing counts of job strain may strengthen the relationship. Though some significant findings were reported (discussed within Chapter 6), there was no consistent evidence that job strain accumulated to impact subsequent BMI or that an accumulation may be associated with BMI differentially dependent upon baseline BMI. Whilst three outliers were identified in analyses of females that warrant further attention in future investigations, this small group could not be investigated within the scope of this thesis where population health and trends are focal.

7.2.5 Summary of Contributions

Collectively, this program of research represents a deep dive investigation into whether there is relationship between job strain and BMI. Beginning with a sound rationale to theorise a relationship (in the introductory chapter), each analysis chapter then explored the prior literature, identifying conceptual and analytic gaps to be addressed. The contributions of each analysis chapter have been outlined above, but overall, when this program of research is considered in its whole entirety, a further original contribution is made. This thesis provides a comprehensive investigation of longstanding limitations in the prior literature (i.e., the inconsistency amongst findings), and the issues highlighted and explored within this thesis (i.e., the benefits of analysing modest BMI variation over time) have not previously been thoroughly considered. Thus, this program contributes considerable knowledge and exploration to investigating whether job strain is associated with BMI.

The analysis of the same dataset throughout has enabled this deep-dive investigation: the consistency of null findings strengthens the conclusion that job strain is not associated with BMI within the population analysed. Given the varied results of other investigations, including varied results within the same population dataset (i.e., Shields et al., 1999; Azagba & Sharaf, 2012), the consistency of these findings is a valuable addition to the body of literature. Amongst the mixed findings reported, the comprehensive approach taken in this thesis overall supports existing studies that have similarly found no evidence for an association of job strain with BMI (i.e., Azagba & Sharaf, 2012; Kivimäki et al., 2015).

The consistent examination of BMI continuously is another contribution made by the current program of research. The maintenance of BMI continuously in analyses answers calls for more research examining BMI across the distribution (i.e., Lohse et al., 2017; Preston et al., 2015). Evidence suggests there is value in examining modest variation in BMI for health (i.e., Zheng et al., 2017; Zimmerman et al., 2013), which translates into economic benefits

(considering the impact of health at a population level). Whilst no robust evidence was found for an association of job strain with BMI continuously, the contribution of this thesis remains valuable and points towards investigating other work contexts and mechanisms that might drive BMI (discussed more below). Given BMI reflects overweight and obesity, these contributions extend indirectly to building knowledge about overweight and obesity also.

This thesis also furthers knowledge and practice of using appropriate longitudinal modelling techniques to answer questions about work environments and health. Multi-level models offer many benefits for analysing longitudinal data as they can account for complex variance within and between people (Singer & Willet, 2003; Torres-Reyna, 2007), which is often a better fit for the high degree of heterogeneity evident in BMI (Wang et al., 2019). Indeed, the results of the analyses in Chapter 4 indicated that the majority of the variance in BMI existed between-individuals at baseline, rather than within individuals over the study period, supporting the need for longitudinal models that look at within-person change over time rather than just capturing between-person differences in cross-sectional research.

However, within the literature to date, the use of random- and fixed- effects multi-level models to analyse job strain with BMI has been limited. The use of these modelling techniques here provides an example of how these models can be adopted to advance research in this area. These investigations appear to be the first to use random-effects models to investigate a possible time-lag between exposure to job strain and subsequent BMI (i.e., the lagged effects model) and the first to use a random-effects model examining four measurements of job strain (the general random-effects model) alongside modelling job strain at baseline exclusively. In the past literature, findings modelled with random effects rested upon analyses of either job strain at baseline only (i.e., this was the only measure of job strain available in certain studies, it was not a choice), or alternately, upon the findings of just one other random-effects multi-level model analysing multiple counts of job strain (i.e., Azagba

& Sharaf, 2012). By analysing these same models using the same dataset, it removes some of the uncertainty around whether differences in findings are due to sample/contextual differences. This also provides much needed replication of prior results and conclusions (i.e., the null findings of Azagba & Sharaf, 2012, and of Kivimäki et al., 2015).

7.2.5.1 Summary of Contributions to Australian Research

The original contributions of the research program collectively are highlighted especially within the Australia context. A paucity of research on job strain and BMI within the Australian workforce was highlighted throughout the review of prior literature in each of the analyses chapters. This thesis has furthered cross-sectional knowledge on job strain and BMI in Australia: just two related cross-sectional studies had been conducted prior (Bean et al., 2015; Ostry et al., 2006), though only one analysed job strain specifically. The results of these prior studies suggested the possibility of an association of job strain with BMI, though the evidence was not strong. Accordingly, Bean et al. and Bean (2015; 2017) noted the need for more robust Australian research. The discrepant results of the current program of research (i.e., null findings) with the findings of the prior Australian studies (i.e., weak evidence for a possible association), raise new important questions about why the findings are not consistent. Further, the simultaneous cross-sectional modelling of continuous and categorical BMI in this thesis is valuable within the Australian context. In the prior Australian investigations BMI was only modelled continuously. Thus, it appears this is the first investigation of job strain with overweight and obesity within Australia.

In line with Bean et al. and Bean's (2015; 2017) recommendations for further Australian research, this thesis appears to be the first longitudinal examination of job strain and BMI using Australian data (although there have been published studies that have looked at psychosocial job quality more broadly, i.e., Magee et al., 2010; Taouk et al., 2019), with a larger sample size than previous research, and stratified analyses to explore the possibility of

differences by sex. Further, the contributions made by examining the potential influence of baseline BMI, and the examinations of increasing counts of job strain with later BMI, are accentuated within the Australian context. In Australia, the current thesis appears to be the first investigation to have tested each of these conceptualisations for how job strain may be related to BMI.

7.3 Strengths and Limitations

This thesis took a comprehensive exploratory approach to examining whether job strain is associated with BMI using quantitative population data. Each of the analyses in the current thesis used data from participants enrolled in the PATH Through Life study, a large-scale longitudinal community-based survey from the ACT and Queanbeyan surrounds. The analyses used data sampled repeatedly from the participants every four-years, over a lengthy 12-year follow-up period. The investigations built-on from each other to examine and clarify issues identified throughout the prior literature and analyses. A particular strength is the development of the longitudinal analysis chapters, where initial explorations and analysis of a longitudinal relationship built into analyses investigating whether baseline BMI may be important in this relationship, and finally went on to test evidence for a cumulative effect of job strain. An additional strength is that the findings presented here may be more generalisable to males and females specifically as all the analyses were stratified by sex, where previous investigations often combined sex within analyses. Within Australia, the findings here are likely more generalisable compared to past research, which used smaller samples of working populations and had only used cross-sectional analyses to test continuous BMI outcomes (Bean et al., 2015; Ostry et al., 2006). However, there are important limitations to be acknowledged. Limitations specific to each analysis have already been discussed within the respective chapters. Below is an acknowledgement of limitations that are more general to the thesis as a whole.

First, the sample was drawn from an area with a relatively high socioeconomic status (SES). Compared to other Australian areas and cities, the Australian Capital Territory has both the highest proportion of people living in relatively advantaged areas and has the lowest proportion of individuals in the most disadvantaged areas (ABS, 2018). The higher SES of the sample drawn, compared to the national average, is a known limitation of the PATH dataset (Anstey et al., 2020). On this, the high SES profile may underrepresent individuals experiencing job strain, which introduces bias. Concurrently, average BMI increase is slower, and rates of overweight and obesity disproportionately lower, amongst higher SES individuals, families and areas (Hayes et al., 2015; Calder, 2019). This combination of factors would likely result in an underestimation of the size of an association between BMI and job strain across all analyses and should be considered when generalising the results both within Australia and internationally, where socioeconomic status may be lower.

The current study used participants' observations when they were employed with information on the job demands and control scales for inclusion in analyses. This is likely to have introduced some bias through the healthy worker effect, where individuals with better quality employment are more likely to stay employed and have better health than those who have poorer quality work (Kuper & Marmot, 2003). Aligned with this, the longitudinal nature of the study may have biased the sample over time. Typically, those who remain active within longitudinal studies can do so due to having greater resources and less stresses to manage within their lives (Teague et al., 2018). Further, the standard construction of job strain was employed here, where job demands and control scores were dichotomised at the sample median. Whilst this has been well-validated in the literature and was selected to enhance the cross-comparison of the current results with others, it is possible this biased the results towards the null through misclassifying those who scored at the median (Fujishiro et al., 2015). A more adverse measure of job strain (i.e., using tertiles as a cut-point to capture

those with even higher demands and lower control) may have reduced the chance of misclassification. When considered within the context of the already high SES profile of the cohort, the healthy worker effect, and the longitudinal nature of the study, this misclassification may have obscured an association of job strain with BMI.

The length of time between follow-ups is another recognised limitation of the PATH dataset (Anstey et al., 2020). Each cohort was re-interviewed every four years, which, whilst allowing follow-up over a lengthy time (12-years in this thesis), may have limited capturing a connection between job strain with BMI. Measures of BMI more proximal in time to experiences of job strain may be more revealing of an association. Further, the long time between measurements make it difficult to infer whether job strain has been experienced episodically throughout the study or continuously. This limitation is particularly relevant to the discussion on whether the chronicity of job strain may be associated with BMI over time. Long periods of time (four-years) passed between measurements and it is not known whether experiences of job strain continued from one measurement to the next, or if job strain was experienced between measurements. As it stands, the current thesis operationalised chronicity as an accumulation of job strain counts over time (i.e., more of a frequency than a duration assessment). This approach assumes that the amount of time experiencing job strain, or the intensity of job strain, was greater with more counts.

7.4 Future Research Directions

Although the results of this program of research suggest reducing job strain is not an effective target for slowing the population increase of BMI over time, the evidence is clear that work stress and increasing BMI are important population health issues within Australia and globally. Each are associated with increased burden of disease, economic liability, and sub-optimal individual outcomes (Crosland et al., 2019; McTernan et al., 2013; Nixon et al., 2011; Stommel & Schoenborn, 2010). Thus, before we implement the findings from this

program of research and consider turning away from job strain as a possible risk factor for higher BMI, towards other modifiable factors, further investigation, replication and consideration of the current findings is required.

In contrast to the findings of this thesis, others have found some evidence to suggest an association of job strain with BMI (i.e., Fujishiro et al., 2015; Klingberg et al., 2019). Although, it is important to reiterate that those studies which have detected a statistically significant association note the very small effect size, and other high-quality studies have also found no association (Azagba & Sharaf, 2012; Kivimäki et al., 2015). While this raises questions about the impact (and utility) of real-world practices or programs targeting job strain as an effective modifier of BMI outcomes, including overweight and obesity (Nyberg et al., 2012), the limited evidence does not necessarily lead to the conclusion that experiencing stress at work is not important for BMI. Such a conclusion is largely inconsistent with other theories and evidence describing how work and health are related (as described in the introduction of this thesis). For example, ecosocial and multi-level theories argue that our focus should be more on the intersection of multiple factors, rather than isolating the effect of individual factors such as job strain, when aiming to understand how environmental contexts (like the workplace or job factors) influence public health (Levins & Lopez, 1999). The sections below present options for expanding on the contributions made by this thesis, including opportunities to replicate the analyses in further population-based longitudinal research, moving beyond job strain to create and explore more multi-faceted representations (and measures) of work stress, and considering more objective assessment of weight gain.

7.4.1 Need for Replication

The findings from this program of research collectively represent an in-depth, comprehensive exploration of a possible association between job strain and BMI. However,

given the inconsistency in previous findings, and the lack of an association found in this thesis, replication studies are still needed in the Australian context and internationally. This thesis has previously outlined that within Australia there is a distinct lack of knowledge and research investigating job strain in association with BMI, with only two prior studies (Bean, 2015; Ostry et al., 2006). Each of these found some evidence of an association within Victorian and South Australian working samples, but this is not supported in the current thesis, prompting the need for further Australian studies. Within Australia, the HILDA and the LSAC nationally-representative datasets could be used to further explore longitudinal associations between job strain (and other psychosocial job conditions) and BMI.

There is also a need for further studies internationally: population average BMI increase is a global phenomenon, as is the increasing prevalence of job strain (American Psychological Association, 2020; National Health and Medical Research Council, 2013; WHO, 2000; UK Health & Safety Executive, 2019). Whilst there are some null findings in other international datasets aligning with the present research (e.g., Azagba & Sharaf, 2012; Kivimäki et al., 2015), there is much room for further high-quality investigation to provide replication. Those datasets that have previously found an association could be replicated (or updated) using more advanced longitudinal modelling. For example, Brunner et al. (2007) reported evidence for an association of job strain with obesity, including incident obesity, in the British Whitehall sample of public servants. Further, Klingberg et al. (2019) similarly reported an association of job strain with overweight and obesity over a lengthy follow-up in a Swedish working population-based cohort. Brunner et al. and Klingberg et al. used logistic regression techniques, but perhaps their datasets could be reanalysed applying more comprehensive longitudinal modelling to help consolidate the literature on this issue (i.e., clarification, consistency).

The need for replication is highlighted further when discussing analyses examining the possible influence of baseline BMI. The results from this program of study indicate that baseline BMI does not compound or reduce future associations between job strain and BMI, contrasting with other evidence suggesting there may be some individuals who are more vulnerable based on their initial BMI (i.e., Fujishiro et al., 2015; Klingberg et al., 2019). This evidence suggests that those already high in BMI may experience greater BMI increase. This aligns with Australian research suggesting that those higher in BMI will experience health and social inequality disproportionately from those with healthier BMIs (Hayes et al., 2019; Jia et al., 2016; Lung et al., 2019). The potential for an interaction of job strain with baseline BMI, though not evidenced in this thesis, would benefit from further systematic and comprehensive analyses and investigations.

7.4.2 Composite Measures of Work Stress

It is widely accepted that work affects health (Bambra, 2011; Marmot et al., 2006; Siegrist & Marmot, 2006; Schnall et al., 2009). However, explaining how work affects health can be complex, with many different variables that are important. One adaptive way to explain the relationship of work and health is by describing the various ‘levels’ at which work can affect the health of workers. For example, the ecosocial framework describes the various levels or contexts via which work might influence health (Krieger, 2001). These levels are described by their proximity or distance from the individual worker. Proximal variables might include characteristics of the workers, whilst more distal variables may include the work environment (including the social landscape of work), or higher levels such as the organisational structure of work and government policies (Krieger, 2001; Masood & Reidpath, 2017). Given the prior literature suggests a weak relationship between job strain and BMI (at best), it is possible that combining job strain with other measures of work stress (either across the varying levels from which work can influence health or multiple indicators

at the individual level) would provide stronger, more consistent findings. Exploring the possible contributions of job strain within the broader context of work stress, may be more fruitful in future research directions.

Work-related stress is a major costing to both organisations and national economies (Brijnath et al., 2014; Safe Work Australia, 2019; Smith, 2010; Medibank Private, 2013). It is associated with lost productivity, absenteeism, presenteeism, and high employee turn-over (Dollard et al., 2000; McTernan et al., 2013; Soderbeg et al., 2014; Suominen et al., 2007; Wang et al., 2009, 2014, 2019). As outlined in the introduction, work stress is an increasingly prevalent phenomenon globally and in Australia. Job strain is one (specific form) of many conceptualisations of the broader work stress phenomenon. Other measures of work stress emphasise the balance between effort and reward for employees (Effort-Reward Imbalance model: Peter & Siegrist, 1997; Siegrist, 1996), and the importance of social support (JDCS model: Johnson & Hall, 1988; Karasek, 1979; Karasek & Theorell, 1990) and resources at work (Job Demands-Resources model: Demerouti et al., 2001), amongst others. These alternative conceptualisations point towards the importance of variables other than demands and control in determining work stress.

Given the multi-factorial nature of BMI and aetiology of overweight and obesity, a composite measure of various conceptualisations of work stress may better account for variations in BMI over time together, rather than any one aspect (or measure) of work stress alone. Others have similarly recognised this and suggested that a cumulative index more representative of work stress as a whole may demonstrate stronger associations with BMI, including overweight and obesity (Bean, 2017; Nyberg, 2017). An Australian study investigating the longitudinal association between psychosocial job quality and BMI supports this. Taouk, Milner and LaMontagne (2019) constructed a multi-dimensional factor of overall job quality, from measures of job demands, job control, job complexity, and perceptions of

unfair pay. They used this composite measure to indicate the number of job adversities experienced over an 8-year period from 2006-2013. They found evidence for job adversity (the poorest job quality- indicated by experiencing 3-4 job stressors) to be associated with increased BMI for females, though not for males. Further, they found a dose-response pattern of association, where BMI increased with cumulative exposure to job stressors (up to a total of 3-4 counts of job adversity). Their results were based on data from a nationally representative sample of Australians, evidencing the generalisability of their results within Australia.

High job demands and low job control, the components of job strain, were featured as job stressors in the composite factor representing job adversity used by Taouk, Milner and LaMontagne (2019). This implies that job demands and control, the elements of job strain, may be important factors from the psychosocial work environment related to increasing BMI, but they may be better placed as indicators when set amongst the context of other relevant working characteristics, as in Taouk et al. (2019). Examining the relationship of psychosocial work stressors with BMI through multi-level models may help explain why more holistic, composite measures may demonstrate stronger associations with BMI. Theorell (2014) notes that the further the distance between a variable on a distal level (such as the work environment), with a disease outcome, the weaker the association should be expected. This is because there are many other variables filling in the 'space' between the variable under study with the outcome. Guided by this, the work environment represents variables distal from BMI, that is itself an outcome proximal to the worker and worker's health. From such a distance, it may be the case that the job demands and control model defining job strain, is too specific. Conversely, more general, composite indicators of work stress may capture more variance across different levels and distances to BMI.

7.4.3 Other Indicators of Excess Adiposity

A further direction for future research on job strain and BMI is the examination of other measures of adiposity, particularly waist circumference or other measures of central adiposity. BMI is utilised as a population health indicator of excess adiposity and is known to be associated with heightened risk for disease and ill-health (Haby et al., 2011; James et al., 2004; Stommel & Schoenborn, 2010) BMI is considered an acceptable indicator and is highly correlated with other measures such as waist circumference (WC) and waist-hip ratio (WHR) (Flegal & Shepherd, 2009). However, measures of central excess adiposity may be better suited in examinations of job strain and health and disease outcomes. Whilst BMI infers the overall adiposity level, central measures of adiposity such as WHR and WC, indicate excess adiposity disproportionately distributed and accumulated centrally on the body. Excess adiposity closer to the internal organs demonstrates stronger associations with health and disease outcomes (Haregu et al., 2020). Importantly, there is evidence that chronic stress is associated more strongly with a central accumulation of excess adiposity (Dallman et al., 2005). Job strain is an indicator of chronic work stress (Karasek, 1998), potentially making waist circumference, or other indicators of central excess adiposity, a more suitable pairing for investigating the relationship of work stress with increasing adiposity.

7.4.4 Summary of Future Research Directions

In summary, this thesis contributes knowledge to directing future research efforts. Whilst replication of the current findings is important, it may be more valuable to extend research towards more composite, holistic measures of work stress in association with BMI and other indicators of excess adiposity. Broad evidence is clear that work affects health, including psychosocial workplace characteristics such as stress generated from work (Bambra, 2011; Clougherty et al., 2010; D'Souza et al., 2003; Marmot et al., 2006; Mauss et al., 2015; Schnall et al., 2009; Siegrist & Marmot, 2006; Schulte et al., 2007). On this, there

is a wide evidence base showing job strain specifically is associated with deleterious health and disease outcomes. It would be unwise to suggest the work environment, including work stress, is not an important, modifiable target for slowing the increase observed in BMI at the population level. Others examining work stress, including job strain, in association with BMI advocate for the value of the workplace in preventing BMI increase, overweight and obesity (Bean, 2017; Fernandez et al., 2010; Fujishiro et al., 2015; Taouk et al., 2019). However, it is also the case that in this thesis' investigations, evidence is lacking to suggest job strain is associated with BMI, a reliable population health indicator. Though the lack of evidence found here is consistent with some other prior, high-quality studies, it should not be misinterpreted to prematurely conclude that work stress, a prominent workplace psychosocial characteristic, is not associated with increasing BMI. Instead, the comprehensive investigations here, taken with the inconsistent and weak past findings, suggest future investigations could extend beyond job strain as a sole measure of exposure, to identify how psychosocial work stress and interactions across multiple exposures may be associated with excess adiposity levels.

7.5 Final Comments

Despite what is known more broadly about the deleterious health outcomes associated with job strain, the evidence from this thesis shows little support that targeted interventions reducing job strain would meaningfully reduce BMI at a population level. However, it is premature to conclude there is no relationship between job strain and BMI. To conclude that job strain does not impact BMI, further replication of the evidence presented here is needed (internationally and in other Australian datasets). It is clear that psychosocial work stress is increasing simultaneously with continued increases in population BMI levels and the prevalence of overweight and obesity. Each of these are major public health concerns with implications for rising burden of disease, economic costs, and disease risk. Efforts are needed

to understand the important contributors to each and to formulate successful intervention strategies to slow and prevent further increases.

Jobs and work are ubiquitous across the lives of most individuals. This, in combination with the knowledge and evidence that work affects health, suggests value in continuing efforts to examine how psychosocial work stress, including job strain, may be associated with increased weight gain (and overweight and obesity). The null findings from this thesis may be most informative for directing future research efforts within Australia and internationally. The comprehensive investigations (and the consistency in the findings) point towards future investigations adopting high-quality population-based, longitudinal data to holistically explore job strain and other indicators of (and contexts relevant to) work stress to identify possible associations with not only BMI, but also other indicators of adiposity levels.

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Appendix A: PATH Through Life Survey Invite to Participate

Letterhead

PATH Through Life Project:

20+, 40+ -Wave 1

Dear

We are asking your help with a medical research project we are conducting on health and well-being of people aged 20-24. This study involves a randomly selected sample of people in this age group living in Canberra or Queanbeyan.

The aims of the research and what we are asking of you are explained in the enclosed information brochure.

An interviewer will contact you in the near future to ascertain if you were **aged 20-24 on the 1st January 1999** and to ask if you are willing to help us with this research. If you are willing, an appointment will be made to see you at a convenient time and place. Because we do not know your exact age, it is possible that you are not in the age group we are researching. **If you are not in the required age group, we would appreciate it if you could contact Karen Maxwell on 62492741 or email her on Path@anu.edu.au.**

We realise that many people rely on mobile phones these days and that others are not listed in the telephone directory under their own name. If this is true for you, we would like you to telephone us to tell us whether you would be interested in taking part in our study.

We very much hope you will agree to take part. We appreciate that it takes time and effort on your part to be part of a study like the present one. However, very little is known about the health of young adults and the success of a study such as this depends on a very high participation rate from the community.

Yours sincerely

Professor Scott Henderson

Letterhead

PATH Through Life Project:

60+ -Wave 1

I.D. No. <<I.D.>>

19 March 2001

<<Title>> <<Given Names>> <<Family Name>>

<<POAdd1>>

<<POAdd2>>

<<POAdd3>>

<<POAdd4>>

Dear <<Title>> <<Family Name>>

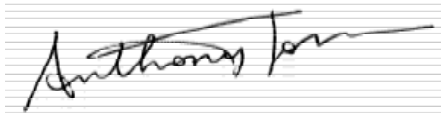
We are asking your help with a medical research project we are conducting on health and well-being of people aged 60 to 64. This study involves a randomly selected sample of people in this age group living in Canberra or Queanbeyan.

The aims of the research and what we are asking of you are explained in the enclosed information brochure.

An interviewer will contact you soon to check if you would be willing to take part, and if so, to make an appointment to see you at a convenient time and place. Alternatively, you can contact Karen maxwell on 6125 8417 or Free Call 1800 666 973, to discuss your participation with her. Karen can also be emailed on PATH@anu.edu.au.

We very much hope you will agree to take part. We appreciate that it will take time and effort on your part. However, very little is known about why some people have better health and well-being than others and so the success of this study depends on as many people as possible participating.

Yours sincerely,

A handwritten signature in black ink, appearing to read 'Anthony Jorm', is written over several horizontal lines.

Professor Tony Jorm

Appendix B: Ethics Approval



THE AUSTRALIAN NATIONAL UNIVERSITY

ETHICS IN HUMAN EXPERIMENTATION COMMITTEE

Outcome of consideration of Protocol

Protocol No. M9807

Date of Submission: 1 September 1998

Project Title: PATH through life project.

Submitted by: Professor A F Jorm

On behalf of the Ethics in Human Experimentation Committee,

I approve/~~do not approve~~ the above protocol.

Approval is subject to the following conditions:

*A sample copy of questionnaire should be provided for
attachment to the protocol.*

Reasons for non-approval:

Review due: _____

Chairperson: _____

(Dr Peter McCullagh)

Date: _____

22/5/98

* This has now been received. No further conditions.

McCullagh 1/10/98

THE AUSTRALIAN NATIONAL UNIVERSITY



RESEARCH SERVICES OFFICE

Human Ethics Officer
Sylvia Deutsch

CANBERRA ACT 0200 AUSTRALIA
TELEPHONE: +61 2 6125 2900
FACSIMILE: +61 2 6125 4807
EMAIL: Sylvia.Deutsch@anu.edu.au

11 November 2002

Professor Anthony F. Jorm
Director
Centre for Mental Health Research
The Australian National University
ACT 0200

Dear Professor Jorm,

Protocol 2002/189
The PATH through life

On behalf of the Human Research Ethics Committee I am pleased to advise that the above protocol has been approved as per the attached *Outcome of Consideration of Protocol*. Please note that as a formality this approval is subject to formal ratification by the Committee at its next meeting on 29 November 2002.

For your information:

1. Under the NHMRC/AVCC *National Statement on Ethical Conduct in Research Involving Humans* we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research and whether it proceeded according to the plan outlined in the above protocol.
2. Please notify the Committee of any changes to your protocol in the course of your research, and when you complete or cease working on this project.
3. The validity of this current approval is five years' maximum from the date shown on the attached *Outcome of Consideration of Protocol* form. For longer projects you are required to seek renewed approval from the Committee.

Yours sincerely,

Sylvia Deutsch
Secretary, Human Research Ethics Committee



THE AUSTRALIAN NATIONAL UNIVERSITY

HUMAN RESEARCH ETHICS COMMITTEE

Outcome of Consideration of Protocol

Researcher: Professor Anthony F. Jorm
Contact details: Centre for Mental Health Research
Protocol No. 2002/189
Title: The PATH through life
Date on application: 30 September 2002 **Date received in Research Services Office:** 30 September 2002

On behalf of the Human Research Ethics Committee,

I approve/~~do not approve~~ the above protocol.

Approval is subject to the following conditions:

.....
.....
.....

Reasons for non-approval:

.....
.....
.....

Review due:

Chairperson: Hilary Charlesworth Date: 11/11/02

(Professor Hilary Charlesworth)

THE AUSTRALIAN NATIONAL UNIVERSITY

RESEARCH OFFICE

Ms Yolanda Shave
Secretary, Human Research Ethics Committee

CANBERRA ACT 0200 AUSTRALIA
TELEPHONE: (02) 6125 7945
FACSIMILE: (02) 6125 4807
EMAIL: Yolanda.Shave@anu.edu.au

4 January 2007

A/Prof Kaarin Anstey
Centre for Mental Health Research
The Australian National University
ACT 0200

Dear A/Prof Anstey,

Protocol 2006/314
The PATH Through Life Project - Wave 3 (PATH)

On behalf of the Human Research Ethics Committee I am pleased to advise that the above protocol has been approved as per the attached *Outcome of Consideration of Protocol*.

For your information:

1. Under the NHMRC/AVCC *National Statement on Ethical Conduct in Research Involving Humans* we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research and whether it proceeded according to the plan outlined in the above protocol.
2. Please notify the Committee of any changes to your protocol in the course of your research, and when you complete or cease working on this project.
3. The validity of this current approval is five years' maximum from the date shown on the attached *Outcome of Consideration of Protocol* form. For longer projects you are required to seek renewed approval from the Committee.

Yours sincerely,



per
Ms Yolanda Shave
Secretary, Human Research Ethics Committee



THE AUSTRALIAN NATIONAL UNIVERSITY

HUMAN RESEARCH ETHICS COMMITTEE

Outcome of Consideration of Protocol

Researcher: A/Prof Kaarin Anstey
Contact details: Centre for Mental Health Research
Protocol No. 2006/314
Title: The PATH Through Life Project - Wave 3 (PATH)
Date on application: 1 November 2006 **Date received in Research Office:** 6 November 2006

On behalf of the Human Research Ethics Committee,

I approve / do not approve the above protocol.

Approval is subject to the following conditions:

.....
.....
.....

Reasons for non-approval:

.....
.....
.....

Review due:

Chairperson: *Prof Lawrence Cram* Date: *21/12/06*

Prof Lawrence Cram

Trish Jacomb

Subject: FW: Human Ethics Protocol 2010/542

THIS IS A SYSTEM-GENERATED E-MAIL. PLEASE DO NOT REPLY. SEE BELOW FOR E-MAIL CONTACT DETAILS.

Dear Prof Kaarin Anstey,

Protocol: 2010/542

The PATH Through Life Project - Wave 4

I am pleased to advise your Human Ethics protocol received approval by the Chair of the Human Research Ethics Committee on 03/03/2011.

For your information:

1. Under the NHMRC/AVCC National Statement on Ethical Conduct in Human Research we are required to follow up research that we have approved. Once a year (or sooner for short projects) we shall request a brief report on any ethical issues which may have arisen during your research or whether it proceeded according to the plan outlined in the above protocol.
2. Please notify the committee of any changes to your protocol in the course of your research, and when you complete or cease working on the project.
3. Please notify the Committee immediately if any unforeseen events occur that might affect continued ethical acceptability of the research work.
4. Please advise the HREC if you receive any complaints about the research work.
5. The validity of the current approval is five years' maximum from the date shown approved. For longer projects you are required to seek renewed approval from the Committee.

All the best with your research,

Yolanda

Yolanda Shave
Ethics Manager / rDNA Secretary
Office of Research Integrity
Research Office
Lower Ground
Building 10B, Chancelry
The Australian National University

Acton, ACT 0200

E: human.ethics.officer@anu.edu.au or
yolanda.shave@anu.edu.au

W: http://www.anu.edu.au/ro/ORI/Office/ORI_index.php

T: (02) 6125 7945

F: (02) 6125 4807

CRISCOS Provider Code: 00120C

Appendix C: Tables Reviewing Studies of Job Strain with Obesity from Overgaard, Gyntelberg, and Heitmann (2004)

The tables in this appendix have been reproduced with the authors' permission.

Table C.1

Cross-Sectional Studies: Workload Men—Overall Obesity

Study ref.	<i>n</i>	Population	Measurement of obesity	Adjustment	Association with obesity and psychological job demands	Association with obesity and job latitudes (skill discretion and decision authority)	Association with obesity and job strain
[10]	3179	White collar worker/banker	BMI ^a	No			NS
[12]	1377	Adult hispanic	BMI ^a	Age, smoking	NS (<i>P</i> = 0.057)	NS	NS
[4]	748	Employed	BMI ^b	Age, smoking, education	+ (<i>P</i> = 0.01)	+ (<i>P</i> = 0.046)	+ (<i>P</i> = 0.027)
[2]	1872	Employed	BMI ^a	Age, sex ^c			NS
				Age, sex ^d			+ (<i>P</i> < 0.001)
				No	NS	NS	NS
				Age, demography, work condition, education	NS	NS	NS
[17]	258	Employed	BMI ^a	No	NS	NS	NS
				Age, demography, work condition, physical activity, education	NS	NS	NS
[3]	746	Employed	BMI ^a	No			NS
				Age			NS
[7]	58	Schoolteachers	BMI ^a	No		NS	
[14]	3531	White collar workers	BMI ^a	No	NS	NS	NS
				Age, personality, social support, physical activity, education	NS	NS	NS

+, positive association; NS, no significant association.

^aMeasured.

^bSelf-reported.

^cSubjective assessed psychological workload.

^dObjective assessed psychological workload.

Table C.2

Cross-Sectional Studies: Workload Women—Overall Obesity

Study ref.	<i>n</i>	Population	Measurement of obesity	Adjustment	Obesity–workload association:		
					Job demands	Job latitudes	Job strain
[4]	756	Employed	BMI ^b	Age, sex ^c Age, sex ^d			NS $P < 0.001$
[5]	56	Hospital personnel	BMI ^b	No			– ($P < 0.05$)
[2]	1971	Employed	BMI ^a	No	NS	+ ($P < 0.05$)	+ ($P < 0.05$)
				Age, demography, work condition, education	+ ($P < 0.005$)	NS	NS
[13]	33 689	Nurses	BMI ^b	No			– ($P < 0.005$)
	13 268	Excluded nurses		Age, demography, work conditions, smoking, physical activity, alcohol status, education			– ($P < 0.005$)
[3]	872	Employed	BMI ^a	No			NS
				Age			NS
[7]	98	School teachers	BMI ^a	No		+ ($P 0.010$)	
[14]	3464	White collar workers	BMI ^a	No	NS	NS	NS
				Age, personality, social support, physical activity, education	NS	NS	NS

+, positive association; NS, no significant association; –, negative (inverse) association.

^aMeasured.

^bSelf-reported.

^cSubjective assessed psychological workload.

^dObjective assessed psychological workload.

Appendix D: Job Demands and Control Analyses and Sensitivity Analyses

D.1 Measures

Job demands and control, as integral variables used to construct and indicate job strain, are described in detail in the methods chapter (Chapter 2). However, a brief overview of each is provided below.

D.1.1 Employment, Job Quality, and Overweight and Obesity Measures

D.1.1.1 Job Demands and Control

The items comprising the job demands and control scale (Cronbach's alphas .65 and .86 respectively) were taken from the Whitehall study (Department of Epidemiology & Public Health, 1991), which was modelled from the JCQ (Bosma et al., 1997). The items from each scale were responded to using a 1–4 point Likert scale (from 'often' to 'never') and were then summed to create a scale for job demands that ranged from 4 to 16, as well as a summary scale for job control that ranged from 7.5 to 30. Scores on the job demands and control scales were then median split (as has been done in prior research, e.g., Amick et al., 1998; Nyberg et al., 2012; Ostry et al., 2006) to create dichotomised high and low job control (median = 24) and high and low job demands (median = 11) categories. For job control, '0' represented high (scores above median scores) and '1' represented low (scores below median), such that higher control (the higher quality job condition) acted as the reference category in the analyses. For job demands, '1' represented high (scores above medium) and '0' represented low scores (again, such that the reference category represented the higher quality job condition).

D.2 Statistical Analyses

Two sets of models were conducted to explore the association between the job strain characteristics (high job demands and low job control) and BMI outcomes, each repeated stratified by sex. The first models were Multinomial Logistic Regression Models (MLRMs), and modelled BMI as a categorical variable with normal weight as the reference category comparing risk with overweight and obese. The second set of models were Linear regressions, and essentially repeated the MLRMs, but modelled BMI as a continuous variable. In both sets of models, high job demands and low job control were tested for a univariate relationship with overweight, obesity, or BMI (the dependent variable). Covariates were included after univariate models creating a sequence of models with the pattern: Model A: high job demands; Model B: low job control; Model C: high job demands and low job control; Model D: high job demands and low job control with covariates.

D.3 Results

D.3.1 Descriptive Statistics and Sample Characteristics

Tables D.1 and D.2 show the descriptive statistics for job demands and control in continuous and categorical form. As per the median split used to create the job strain categorical variables, just under half of males reported low job control, whilst just over half of females reported low job control. However, the percentage of males reporting job demands was higher than that for females.

Table D.1*Descriptive Statistics for Categorical Job Control and Demands by Sex*

Variable		Males			Females		
		N=1,944	%	% Miss.	N=1,978	%	% Miss.
Job control	Low	832/1,944	42.80	0	1077/1,978	54.45	0
Job demands	High	887/1,944	45.63	0	820/1,978	41.46	0

Note. This table includes data from all employed participants at wave 2 who have data on job characteristics and with those whose BMI >50 excluded (n=6). The numbers included in the final analyses were slightly lower based on complete cases analyses (e.g. final analysis n=1774 males and 1745 females).

Table D.2*Descriptive Statistics for Continuous Job Demands and Control Variables by Sex*

Variable	Males			Females		
	N=1,944	M (SD)	% Miss.	N=1,978	M (SD)	% Miss.
Job control	1,944	23.75 (3.45)	0	1,978	22.94 (3.52)	0
Job demands	1,944	11.29 (2.11)	0	1,978	11.06 (2.20)	0

Note. This table includes data from all employed participants at wave 2 who have data on job characteristics and with those whose BMI >50 excluded (n=6). The numbers included in the final analyses were slightly lower based on complete cases analyses (e.g. final analysis n=1774 males and 1745 females).

D.3.2 Multinomial Logistic Regressions***D.3.2.1 Job Demands and Control***

Four multinomial regression models were conducted using job demands and control as predictor variables of overweight and obesity compared to normal weight controls. Table D.3 shows that in model A, high job demands were not a significant predictor of overweight or obesity in males. However, model B shows that males with low job control were less likely to be overweight or obese though the probability of this association $p = .049$ for overweight, and $p = .024$ for obese males, does not provide compelling evidence for the rejecting the null hypothesis. The significant

reduction in risk for those males with lower control remained when job demands and job control were entered simultaneously in model C, with job demands remaining non-significant. However, the significance of job control was attenuated when the model was adjusted for all relevant covariates (model D, Table D.4). Further testing by entering each covariate separately into the regression with job control to predict overweight and obesity, showed that controlling for the relationship between age and BMI accounted for the significant relationship between job control and BMI (a reflection of the finding that men in the older age group (44–48 years) experience both higher job control and are more likely to be overweight or obese). To further verify this association, multinomial models were run separately by age group for men and found no significant relationship between job control and BMI category for either the 20s or 40s age cohort. Separating the males based on age-group and testing the univariate association between job control and overweight and obesity using a chi-square test also showed no significant differences within either age-group (20s male cohort $\chi^2=1.784$, $p=.410$; 40s male cohort $\chi^2=.021$, $p=.989$). For females, neither job demands nor control indicated any significant probability of either increasing or decreasing the likelihood of overweight or obesity relative to normal weight individuals (see Tables D.3 and D.4).

Table D.3

Univariate Multinomial Regression Models (A–C) Predicting Overweight and Obesity from Job Strain, High Job Demands and Low Job Control in Males and Females

Model A		RRR Ov.	P	95% CI		RRR Ob.	P	95% CI	
Males	High job demands	1.02	.827	0.83	1.25	1.14	.345	0.87	1.51
Females	High job demands	1.11	.374	0.32	0.44	1.14	.307	0.89	1.47
Model B		RRR Ov.		95% CI		RRR Ob.		95% CI	
Males	Low job control	0.81*	.049	0.66	1.00	0.72*	.024	0.54	0.96
Females	Low job control	1.00	.987	0.79	1.26	1.09	.509	0.85	1.40
Model C		RRR Ov.		95% CI		RRR Ob.		95% CI	
Males	High job demands	1.01	.925	0.82	1.24	1.12	.421	0.85	1.48
	Low job control	0.81*	.050	0.66	1.00	0.73*	.028	0.55	0.97
Females	High job demands	1.11	.374	0.88	1.40	1.15	.293	0.89	1.48
	Low job control	1.00	.981	0.80	1.26	1.10	.480	0.85	1.41

Notes. Reference category for BMI dependent variable is normal weight. Model C = Job demands only; Model D= Job control only; Model E = Job demands and control. Ov. = overweight, Ob. = obese.

Table D.4

Fully Adjusted Multinomial Regression (Model D) Predicting Overweight and Obesity from High Job Demands and Low Job Control in Males and Females

Model D		RRR Ov.	P	95% CI		RRR Ob.	P	95% CI	
Males	High job demands	0.91	0.401	0.73	1.14	0.96	0.808	0.71	1.31
	Low job control	0.94	0.594	0.75	1.18	0.86	0.332	0.62	1.17
	Age group (40s)	1.42	0.02	1.06	1.92	1.81	0.005	1.19	2.74
	Smoke (No)	1.06	0.689	0.81	1.39	1.16	0.45	0.79	1.68
	Children (No)	0.59	<.001	0.44	0.79	0.61	0.017	0.41	0.92
	Exercise (Moderate)	0.99	0.975	0.72	1.37	0.54	0.001	0.37	0.79
	Exercise (Vigorous)	1.13	0.449	0.82	1.56	0.42	<.001	0.28	0.63
	Finance prob. (Yes)	1.08	0.624	0.80	1.44	0.92	0.698	0.62	1.38
	Mental health	0.99	0.329	0.98	1.01	1.00	0.955	0.98	1.02
	Physical health	0.99	0.246	0.97	1.01	0.96	<.001	0.93	0.98
	Education	0.95	0.099	0.90	1.01	0.86	<.001	0.80	0.93
	Job hours	1.01	0.016	1.00	1.02	1.02	0.012	1.00	1.03
	Constant.	3.85	0.057	0.96	15.47	27.18	<.001	4.47	165.31
Females	High job demands	1.11	0.425	0.86	1.42	1.09	0.534	0.82	1.45
	Low job control	1.01	0.94	0.79	1.30	1.00	0.975	0.75	1.32
	Age group (40s)	1.36	0.091	0.95	1.94	1.42	0.082	0.96	2.12
	Smoke (No)	1.13	0.449	0.83	1.54	1.28	0.16	0.91	1.82
	Children (No)	0.70	0.051	0.49	1.00	0.67	0.056	0.45	1.01
	Exercise (Moderate)	0.81	0.145	0.61	1.07	0.70	0.019	0.52	0.94
	Exercise (Vigorous)	0.60	0.003	0.44	0.84	0.39	<.001	0.26	0.58
	Finance prob. (Yes)	1.18	0.286	0.87	1.60	1.17	0.358	0.84	1.63
	Mental health	1.01	0.474	0.99	1.02	1.00	0.605	0.99	1.02
	Physical health	0.97	0.006	0.96	0.99	0.93	<.001	0.91	0.95
	Education	0.93	0.027	0.87	0.99	0.83	<.001	0.77	0.89
	Job hours	1.01	0.099	1.00	1.02	1.02	<.001	1.01	1.03
	Constant.	2.67	0.171	0.65	10.89	65.96	<.001	14.75	295.01

Note. Model F = Job demands and control with covariates. Ov. = overweight, Ob. = obese.

D.3.3 Multiple Linear Regressions

The relationships of the JDC subscale components were also modelled with continuous BMI in multiple regression models. Each was maintained categorically with only the dependent variable, BMI, being continuous.

D.3.3.1 Job Demands and Control

Four multiple regression models were run using job demands and control as independent variables in association with continuous BMI (underweight individuals excluded). In males, model A of Table D.5 shows that high job demands were not significantly related to BMI. At model B low job control was a significant predictor of BMI ($p=.022$), indicating low control was associated with lower BMI. When entered simultaneously in a model together (model C), high job demands were not associated with BMI, though low job control remained significant ($p=.027$). The significance of job control was attenuated, however, with adjustment for all covariates in model F. Anticipating the same pattern seen in the multinomial logistic regression analyses between job control and BMI both increasing with age, linear regressions were run separated by age group that showed no significant associations between job control and BMI within either age group.

For females, the testing of any association of high job demands, or low job control, with continuous BMI, showed no evidence of any relationship when entered separately (models A and B, Table D.5) or together (model C, Table D.5), or when modelled with covariates (model D, Table D.6).

Table D.5

Univariate Linear Regression Models Examining the Association of Job Strain, High Job Demands and Low Job Control with BMI in Males and Females

Model A		B	Std. Err.	P	95% CI	
Males	High job demands	0.25	0.19	0.201	−0.13	0.62
Females	High job demands	0.39	0.25	0.118	−0.10	0.89
Model B		B	Std. Err.	P	95% CI	
Males	Low job control	−0.44	0.19	0.02	−0.82	−0.06
Females	Low job control	0.24	0.25	0.347	−0.26	0.73
Model C		B	Std. Err.	P	95% CI	
Males	High job demands	0.22	0.19	0.26	−0.16	0.60
	Low job control	−0.43	0.19	0.03	−0.81	−0.05
Females	High job demands	0.41	0.25	0.11	−0.09	0.90
	Low job control	0.25	0.25	0.31	−0.24	0.74

Note. Model C = Job demands only; Model D= Job control only; Model E = Job demands and control.

Table D.6

Multiple Linear Regression (Model D) Examining the Association of High Job Demands and Low Job Control with BMI in Males and Females

Model D		B	Std. Err.	P	95% CI	
Males	High job demands	−0.02	0.20	0.92	−0.40	0.37
	Low job control	−0.14	0.20	0.48	−0.53	0.25
	Age group (40s)	1.12	0.27	<.001	0.60	1.64
	Smoke (No)	0.47	0.24	0.05	0.00	0.94
	Children (No)	−0.46	0.26	0.07	−0.96	0.04
	Exercise (Moderate)	−1.00	0.27	<.001	−1.53	−0.48
	Exercise (Vigorous)	−1.00	0.27	<.001	−1.53	−0.47
	Finance prob. (Yes)	0.14	0.25	0.57	−0.35	0.64
	Mental health	0.00	0.01	0.93	−0.02	0.02
	Physical health	−0.07	0.02	<.001	−0.10	−0.04
	Education	−0.20	0.05	<.001	−0.30	−0.11
	Job hours	0.02	0.01	0.01	0.01	0.04
	Constant.	32.19	1.18	<.001	29.88	34.51
Females	High job demands	0.23	0.25	0.35	−0.25	0.72
	Low job control	0.13	0.25	0.60	−0.35	0.61
	Age group (40s)	1.07	0.35	<.001	0.38	1.77
	Smoke (No)	0.46	0.31	0.13	−0.14	1.06
	Children (No)	−0.86	0.36	0.02	−1.57	−0.16
	Exercise (Moderate)	−0.64	0.28	0.02	−1.20	−0.09
	Exercise (Vigorous)	−1.36	0.32	<.001	−1.99	−0.72
	Finance prob. (Yes)	0.35	0.30	0.24	−0.24	0.95
	Mental health	0.02	0.01	0.29	−0.01	0.04
	Physical health	−0.17	0.02	<.001	−0.20	−0.13
	Education	−0.30	0.06	<.001	−0.42	−0.17
	Job hours	0.04	0.01	<.001	0.02	0.06
	Constant.	36.16	1.36	<.001	33.49	38.82

Note. Model F = Job demands and control with covariates.

D.4 Sensitivity Analyses

Twenty-six male and 15 female outliers were identified through the calculation of standardised residuals that were greater than three. When the BMI of these males and females was checked, however, BMI was found to range from 40 to 50, which was within the pre-determined study inclusion criteria. In order to examine the influence these outliers may have on the linear regression, analyses were run with and without the inclusion of these outliers. Table D.7 shows that for males the estimate of relationship was only changed at the second decimal place and that in each of model A and B job strain was not significant. For females, the significance of the univariate Model A relationship was decreased notably. However, model B, with adjustment for covariates, saw the significance attenuated. Further, the comparison of the coefficient against analyses containing the outliers (Model A: $B = .54$, $p = .074$; Model B: $B = .36$, $p = .213$, see Chapter 3, Table 3.8) did not show meaningful differences in the estimate of relationship. Further, the retention of outliers in linear regression, if influential, is more likely to have an impact on hypothesis testing (significance estimates) rather than the estimate of relationship. Thus, given careful investigation and consideration the analyses were reported in the main chapter with outliers included.

Table D.7

Sensitivity Analyses: Linear Regression Models Examining the Association of Job Strain with BMI in Males and Females with Outliers Excluded

Model A		B	P	95% CI	
Males	Job strain	−0.38	0.092	−0.83	0.06
Females	Job strain	0.69	0.017	0.13	1.26
Model B		B	P	95% CI	
Males	Job strain	−0.34	0.130	−0.77	0.10
	Age group (40s)	0.98	<.001	0.52	1.45
	Smoke (No)	0.37	0.087	−0.05	0.79
	Children (No)	−0.66	0.004	−1.12	−0.21
	Exercise (Moderate)	−0.70	0.004	−1.18	−0.23
	Exercise (Vigorous)	−0.80	0.001	−1.28	−0.32
	Finance prob. (Yes)	0.08	0.743	−0.38	0.53
	Mental health	0.00	0.746	−0.02	0.02
	Physical health	−0.05	0.001	−0.08	−0.02
	Education	−0.18	<.001	−0.27	−0.09
	Job hours	0.02	0.002	0.01	0.03
	Constant.	30.49	<.001	28.45	32.53
Females	Job strain	0.53	0.057	−0.01	1.07
	Age group (40s)	0.93	0.006	0.27	1.59
	Smoke (No)	0.45	0.120	−0.12	1.03
	Children (No)	−0.86	0.012	−1.53	−0.19
	Exercise (Moderate)	−0.72	0.008	−1.24	−0.19
	Exercise (Vigorous)	−1.47	<.001	−2.08	−0.87
	Finance prob. (Yes)	0.25	0.379	−0.31	0.82
	Mental health	0.01	0.461	−0.02	0.04
	Physical health	−0.14	<.001	−0.17	−0.10
	Education	−0.29	<.001	−0.41	−0.17
	Job hours	0.04	<.001	0.02	0.05
	Constant.	34.96	<.001	32.54	37.39

Notes. Model A = Job strain only; Model B = Job strain and covariates. Analyses run with 26 males and 15 females identified as outliers (>3 standardised residuals) removed.