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Multimorbidity in Thailand: Disease burden, mortality, and geographic distribution

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Declaration

Except where otherwise stated, this thesis is my own work, undertaken from November 2020 to October 2025, at the National Centre for Epidemiology and Population Health, the Australian National University. For the published and submitted papers which form Chapters 4 to 10 of this thesis a full explanation of any contributions and that of each of my co-authors are included in the thesis as Appendix.

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Abstract

Multimorbidity, defined as the coexistence of two or more chronic conditions, poses a significant health challenge in Thailand, particularly during a period of sustained health transition marked by rising prevalence of non-communicable diseases. This thesis explores the patterns, risk factors, spatial distribution, and impact on mortality of multimorbidity among Thai adults, and investigates prevention and management strategies for multimorbidity in Southeast Asia, including Thailand.

A systematic review was conducted to assess multimorbidity prevalence in Southeast Asia and its association with education levels. Data from the Thai Cohort Study were analysed using prevalence-based and latent class analysis, logistic regression, spatial analysis, and survival analysis to examine disease clustering, socio-demographic and lifestyle risk factors, geographic distribution, and mortality disparities. A narrative synthesis was conducted to summarise prevention and management strategies of multimorbidity in Southeast Asian regions.

The systematic review revealed multimorbidity prevalence in Southeast Asia ranging from 3.2% to 72.6% among individuals aged 15 years and above. Analysis of Thai Cohort Study data revealed an overall prevalence of multimorbidity of 10%. Metabolic syndrome components including obesity, hyperlipidaemia and hypertension were major drivers of multimorbidity. Age and gender disparities were observed, with higher prevalence among adults aged 60 years and older and among men. Lifestyle factors such as diet (fast food, p -trend = 0.0446; instant food, p -trend = 0.0313) and sleep duration (more than 8 h, AOR = 1.29, 95% CI 1.07-1.55; less than 6 h, AOR = 1.24, 95% CI 1.09-1.41) were positively associated with multimorbidity, while regular exercise including housework (p -trend = 0.0034) was protective. Spatial analysis highlighted higher prevalence in developed areas such as Bangkok and Central Thailand. Latent class analysis identified four clusters: Relatively healthy (87.32%, reference), Metabolic syndromes (10.20%), Cardiometabolic disorders (1.53%), and Multi-system conditions (0.95%). Older age was associated with an increased risk of belonging to the Metabolic syndromes (p -trend = 0.0314), Cardiometabolic disorders (p -trend = 0.0354), or Multi-system conditions (p -trend = 0.0445) clusters. Male gender was also associated with an increased risk of these clusters, while higher education and frequent housework (Cardiometabolic disorders, p -trend = 0.0025) were associated with a

lower risk. Central Thailand showed a high age-adjusted prevalence of the Cardiometabolic disorders class (1.47%). Survival analysis indicated a 43% higher risk of death for multimorbid individuals compared to non-multimorbid participants, with age, sleep duration, smoking, and alcohol consumption further increasing mortality risk.

This thesis fills research gaps regarding multimorbidity in Thailand and Southeast Asia by providing detailed evidence on prevalence, clustering, socio-demographic and lifestyle determinants, spatial distribution, and mortality impact. The findings highlight the need for targeted prevention and management strategies focusing on metabolic syndrome, age, gender, and lifestyle factors. Tailored healthcare resource allocation in areas with high multimorbidity prevalence is essential to improve outcomes and reduce mortality. Despite increasing research, practical applications in the region remain limited, emphasizing the importance of evidence-based policy, objective data collection, and integrated interventions to alleviate the burden of multimorbidity.

Keywords: Age, Gender, Chronic conditions, Multimorbidity, Thai Cohort Study, Thailand, Southeast Asia

List of Abbreviations

AAS	Australian Active Survey
aBIC	Adjusted Bayesian Information Criterion
AIC	Akaike Information Criterion
AHR(s)	Adjusted hazard ratio(s)
ANU	Australian National University
AOR(s)	Adjusted odd ratio(s)
ARRR(s)	Adjusted relative risk ratio(s)
ASEAN	Association of Southeast Asian Nations
BIC	Bayesian Information Criterion
BLRT	Bootstrap-based likelihood ratio test
BMI	Body mass index
CC(s)	Chronic conditions
CCI	Charlson Comorbidity Index
CHAS	Community Health Assistance Scheme
CHM	College of Health & Medicine
CI	Confidence interval
CIN	Citizen Identification Number
CUPC	Contracting Unit of Primary Care
CVA	Cerebrovascular accident
CVD(s)	Cardiovascular diseases
DALY	Disability-adjusted life year
DHML	District Health Management Learning
ECI	Elixhauser Comorbidity Index
EHRs	Electronic health records
GIS	Geographic Information System
GPs	General practitioners
HICs	High income countries
HIS	Health Information System
HIV	Human immunodeficiency viruses
HR(s)	Hazard ratio(s)

ICD	International Classification of Diseases
IFLS	Indonesian Family Life Survey
LCA	Latent class analysis
LMICs	Low- and middle-income countries
LMR LR	Vuong-Lo-Mendell-Rubin likelihood ratio test
INTs	Insecticide-treated nets
IPAQ	International Physical Activity Questionnaire
MI	Multiple imputation
MICE	Multiple imputation by chained equations
NA	Not available
NS	Not significant
NCD(s)	Non-communicable diseases
NCEPH	National Centre of Epidemiology and Population Health
NEHR	National Electronic Health Record
NGOs	Non-governmental organizations
NLEM	National List of Essential Medicines
NOS	Newcastle Ottawa Scale
NUHS-RHS	National University Health System-Regional Health System Integrated
NICE programme	Interventions and Care Extension
OR(s)	Odd ratio(s)
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analyses
RCTs	Randomised controlled trials
RR	Rural-rural
RRR(s)	Relative risk ratio(s)
RSPH	Research School of Population Health
RU	Rural-urban
SD	Standard deviation
SES	Socio-economic status
SMHS	Singapore Mental Health Study
STOU	Sukhothai Thammathirat Open University
TB	Tuberculosis
TCS	Thai Cohort Study

UCS	Universal Coverage Schemes
UR	Urban-rural
US	The United States
USA	The United States of America
UU	Urban-urban
WHO	World Health Organization
WiSE	Wellbeing of the Elderly in Singapore

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Statement of the publications

This thesis by compilation is based on the following seven papers (all of them were published), to which I have made important contributions as the first author as well as the corresponding author. The contribution of me is outlined in the each chapter (from chapter 4 to chapter 10).

Paper one: Feng X, Kelly M, Sarma H. The association between educational level and multimorbidity among adults in Southeast Asia: A systematic review. *PLoS One*. 2021 Dec 20;16(12):e0261584. doi: 10.1371/journal.pone.0261584 (First author)

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Paper three: Feng X, Sarma H, Seubsman SA, Sleight A, Kelly M. Association of socio-demographic and lifestyle factors with multimorbidity among adults in the Thai Cohort Study. *Journal of Public Health (From Theory to Practice)*. 2025 May 21;2025:1-17. doi: 10.1007/s10389-025-02479-0 (First and corresponding author)

Paper four: Feng X, Sarma H, Bagheri N, Tsheten T, Seubsman SA, Sleight A, Kelly M. The spatial analysis of multimorbidity in Thai Cohort Study. *Archives of Public Health*. 2025 May 7;83:120. doi: 10.1186/s13690-025-01605-4 (First and corresponding author)

Paper five: Feng X, Sarma H, Seubsman SA, Sleight A, Kelly M. Spatial Analysis of patterns of Multimorbidity in the Thai Cohort Study Using Latent Class Analysis. *Journal of Epidemiology and Global Health*. 2025 Feb 12;15(1):24. doi: 10.1007/s44197-025-00352-7 (First and corresponding author)

Paper six: Feng X, Sarma H, Seubsman SA, Sleight A, Kelly M. The Impact of Multimorbidity on All-Cause Mortality: A Longitudinal Study of 87,151 Thai Adults

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Paper seven: Feng X, Sarma H, Kelly M. Prevention and management of multimorbidity in Southeast Asia: A narrative review. *Public Health Challenges*. 2024 Sep;3(3):e218. doi:
10.1002/puh2.218 (First and corresponding author)

Chapter 1 Introduction

1.1 Background

Multimorbidity, which is commonly defined by the World Health Organization (WHO) as the coexistence of two or more chronic conditions in the same individual, has emerged as a critical global health concern in recent decades [1]. This growing phenomenon has serious implications for public health worldwide. As populations continue to age and lifestyle factors evolve, the prevalence of multimorbidity is increasing, placing immense pressure on healthcare systems [2]. The most common conditions contributing to multimorbidity include cardiovascular diseases, diabetes, chronic respiratory diseases, and depression [1, 2]. This situation is particularly challenging as multimorbidity is associated with significantly higher healthcare costs, more complex disease management, and greater mortality risks for individuals suffering from multiple chronic diseases [3]. In many cases, patients with multimorbidity require a coordinated, integrated approach to care, which often involves multiple healthcare providers working together. However, many healthcare systems, especially in low- and middle-income countries (LMICs), are not equipped to offer such multidisciplinary care, leading to suboptimal outcomes for these patients [3, 4].

As the global population continues to age, the burden of multimorbidity is expected to increase further. By 2050, individuals aged 65 years and older are projected to account for one-sixth of the total population, exacerbating the prevalence of multimorbidity [3]. In high-income countries (HICs), multimorbidity has already become a major health challenge, with more than 60% of older adults affected by at least two or more chronic conditions [4]. Additionally, the economic burden is also significant, with annual healthcare costs for multimorbidity patients reaching up to 150,000 USD in certain settings [3-5].

However, multimorbidity is no longer confined to older adults. In recent years, a growing number of studies have focused on multimorbidity among younger populations, highlighting that lifestyle factors, such as poor dietary habits, sedentary behaviour, and chronic stress, can have profound long-term health implications [5]. For instance, existing research indicates that

approximately one-quarter of adults under 60 worldwide already have two or more chronic conditions [5]. Notably, conditions traditionally associated with aging, such as obesity, hypertension, and diabetes, have emerged in certain younger populations [6].

The implications of multimorbidity extend far beyond physical health. While it is well-known that the coexistence of multiple chronic diseases negatively affects individuals' physical well-being, it also significantly impacts their mental health. People living with multimorbidity often experience increased psychological distress, anxiety, and depression, which further reduces their overall quality of life [1-3]. Moreover, the financial burdens imposed on individuals and families by managing several chronic conditions can be overwhelming, especially in LMICs where access to affordable healthcare is often limited. These social and economic challenges exacerbate the difficulties faced by people with multimorbidity and contribute to a cycle of disadvantage that is hard to break [5, 6].

The situation in LMICs is particularly concerning. These countries face substantial healthcare challenges, including insufficient infrastructure, limited specialized care for managing chronic diseases, and lower health literacy among the general population [7]. The prevalence of multimorbidity in LMICs is estimated at approximately 36% [6], and has increased by around 50% over recent years, indicating a rapidly growing burden [6, 7]. Economic barriers, such as limited access to medical treatments and preventive care, further exacerbate these challenges, and constraints in access to essential medicines and healthcare services limit the effectiveness of multimorbidity management [7, 8].

As countries develop, there is a well-documented transition in the socioeconomic distribution of multimorbidity [8, 9]. In the early stages of development, higher SES groups often bear a greater burden of chronic diseases due to lifestyle factors such as poor diet and physical inactivity [8-10]. However, as development progresses, this burden increasingly shifts toward lower SES populations, who face greater exposure to occupational stress, environmental pollutants, and food insecurity while wealthier more educated population groups can support healthier lifestyles [8-10]. Consequently, socioeconomic status (SES) has become one of the most significant factors contributing to the rising burden of multimorbidity. Multiple studies have consistently shown that individuals from lower-income and lower-education backgrounds are disproportionately affected by multimorbidity [9-11]. The link between SES

and multimorbidity is complex and multifaceted. These factors, in turn, lead to a higher burden of multimorbidity in disadvantaged populations, highlighting the significant health inequities that exist within and between countries [11, 12]. Furthermore, other demographic factors such as gender, marital status, and urban versus rural residence also play critical roles in determining an individual's risk of developing multimorbidity. However, the specific nature of these relationships varies depending on the cultural, economic, and healthcare contexts of different regions and populations [12].

In addition to, and connected with, these socioeconomic factors, health behaviours are a key determinant of multimorbidity. Health risk behaviours such as smoking, excessive alcohol consumption, and a sedentary lifestyle have long been identified as major contributors to the development of the most common cluster of chronic diseases in terms of cardiovascular and metabolic diseases [13]. Individuals who engage in these behaviours are at significantly higher risk of developing conditions such as cardiovascular diseases, diabetes, and obesity, conditions that commonly coexist and lead to multimorbidity. The growing prevalence of these unhealthy behaviours, especially among younger populations, further exacerbates the challenge of addressing multimorbidity globally [13].

Despite the growing burden of multimorbidity, several important research gaps remain. First, most existing research on multimorbidity focuses on high-income countries, leaving LMICs underrepresented in the literature [7]. While the association between multimorbidity and socioeconomic factors has been widely explored, the causal mechanisms linking these factors remain poorly understood [7, 14]. There is also a lack of life course risk analysis and detailed assessments of how different risk factors interact to influence multimorbidity development, particularly in LMICs where healthcare challenges differ significantly from those in high-income settings [10]. Additionally, more research is needed to better understand the geographical distribution of multimorbidity, the disease burden it imposes on different populations, and how these patterns vary across different cultures and economies [15].

Addressing these research gaps is essential for developing effective public health strategies that can be tailored to the specific needs of diverse populations. By improving our understanding of multimorbidity in different socioeconomic and geographic contexts, we can better equip healthcare systems worldwide to respond to this growing challenge and mitigate

its impact on individuals and societies alike [15]. Only by considering the multifactorial nature of multimorbidity, including its socio-economic, behavioural, and environmental drivers, can we develop policies that effectively reduce its burden and improve the health outcomes of affected populations [11, 12].

1.2 Rationale

Thailand is a lower-middle-income country (LMIC) in Southeast Asia, located in the centre of the Indochinese Peninsula, with an area of 513,000 square kilometres and a population of nearly 70 million [16, 17]. Bangkok is its capital and largest city. With rapid economic and social development, Thailand is gradually transitioning into an aging society, with the proportion of the population aged 65 years and above expected to rise from 13% currently to 31% by 2060 [16, 17]. At the same time, the proportion of the working-age population is projected to decrease from 71% in 2020 to 56% in 2060 [16, 17]. This demographic shift means that Thailand will face more health and social challenges associated with aging in the coming decades.

Meanwhile, Thailand is undergoing a major health transition, with non-communicable diseases (NCDs) gradually replacing infectious diseases as the primary public health challenge [18, 19]. In the past, infectious diseases such as malaria, and maternal and child health challenges, were the main causes of disease burden, but with improvements in health services, public health and health environments, these diseases are receding. This shift, together with the ageing population have led cardiovascular diseases (CVDs), diabetes, and other chronic diseases to become the dominant health concerns [18, 19]. This transition has led to a significant rise in the prevalence of multimorbidity (the coexistence of two or more chronic conditions). Currently, the prevalence of multimorbidity in Thailand is about 10%, reflecting the substantial health burden imposed by chronic diseases [7, 14, 20].

However, despite the growing importance of studying multimorbidity, research in Thailand on key issues such as its geographic distribution, disease burden, and mortality patterns remains relatively limited in scope [20, 21]. These aspects have not been comprehensively examined, particularly in relation to different regions and populations. A more detailed understanding of multimorbidity is needed, especially in a country like Thailand that is undergoing a health transition and facing new challenges in managing chronic diseases [20-22].

This study aims to address these research gaps by utilizing data from the Thai Cohort Study (TCS), a large-scale cohort study that has tracked over 87,000 participants across Thailand since 2005 [18, 23]. By analysing the disease burden, mortality, and geographic distribution of multimorbidity, this study will provide new empirical evidence on how middle-income countries can respond to this growing burden [18, 24]. The findings will not only assist in health policy development in Thailand but also offer valuable lessons and insights for other countries undergoing similar health transitions.

The significance of this study lies not only in filling the research gap on multimorbidity in Thailand but also in providing useful references for other LMICs facing similar health challenges. These countries such as Malaysia and Indonesia are also experiencing rising burdens of NCDs due to aging populations and lifestyle changes [25, 26]. Through this study, we aim to gain a deeper understanding of the trends and socio-economic drivers of multimorbidity, offering data support and theoretical foundations for public health policy development on a global scale.

1.3 The aim

This thesis aims to improve the understanding of multimorbidity in Thailand, including its risk factors, disease clustering, spatial distribution, and mortality impact. In addition, two reviews provide a broader Southeast Asian perspective, examining the association between education (one of the main factors of socio-economic status, SES) and multimorbidity, and exploring prevention and management strategies relevant to the region.

1.4 The objectives

- 1) To identify the regional prevalence of multimorbidity and the socio-economic factors driving it, with an emphasis on education in Southeast Asia.
- 2) To understand the status of multimorbidity via TCS in Thailand, especially the a) disease clustering, b) risk factors and epidemiology, and c) spatial distribution.
- 3) To investigate the impact of multimorbidity and related health-risk factors, including socio-demographic characteristics and health behaviours, on adult survival by analysing the mortality data from the TCS.

- 4) To explore practical and comprehensive multimorbidity prevention and management policies and approaches suitable for Southeast Asian contexts by reviewing existing guidelines and strategies.

1.5 Research questions

The research questions for this thesis are below:

- 1) *How do education and other socioeconomic drivers interact with prevalence of multimorbidity in Southeast Asia?*

Understanding the prevalence of multimorbidity in Southeast Asia, including Thailand, and its association with key health-risk factors is necessary for addressing the region's growing burden of chronic diseases. Educational attainment, a key indicator of socioeconomic status (SES), plays a significant role in shaping multimorbidity patterns. However, existing research on these relationships remains limited, highlighting the need for a comprehensive examination of how SES-related factors contribute to multimorbidity in this context.

- 2) *What are the common clusters of chronic conditions in the Thai Cohort Study (TCS)?*

Understanding the clustering patterns of chronic conditions within multimorbid patients is essential for informing targeted health policy responses. Identifying common disease clusters will aid in developing more effective prevention and management strategies, especially by considering potential differences between males and females. Given the growing burden of multimorbidity, gaining deeper insight into these patterns is crucial for improving healthcare planning and resource allocation.

- 3) *What are health-risk factors for multimorbidity in the TCS?*

Examining the risk factors for multimorbidity in Thailand is particularly important due to the country's unique socio-economic context and health challenges. As Thailand faces a growing burden of chronic diseases, it is essential to identify risk factors such as age, SES, and unhealthy lifestyles that contribute to multimorbidity. Focusing on these factors within the Thai context will help develop more targeted health interventions and inform policies that address the specific needs of the population.

- 4) *What is the spatial distribution of multimorbidity prevalence in the TCS?*

The geographic distribution of multimorbidity in Thailand is crucial for effective prevention, intervention, and treatment strategies. Identifying regional patterns of multimorbidity prevalence helps target health policies to areas with higher or lower rates. Additionally, exploring the demographic, environmental, and socio-economic factors influencing these patterns can guide interventions tailored to the specific needs of different regions.

5) Does multimorbidity increase mortality risk in the TCS?

Similarly, mortality rates are higher for people with multimorbidity compared to those without. However, studies examining this relationship in Thailand remain limited.

Investigating the impact of multimorbidity on mortality, particularly in relation to the number of chronic diseases and associated risk factors, is crucial for understanding the severity of the issue and for developing targeted interventions to improve survival outcomes.

6) How can multimorbidity be prevented and managed in Southeast Asia?

The analysis above provides insights into common models of multimorbidity in Thailand, the associated risk factors, mortality, and geographical distribution. We will examine the prevention and management of multimorbidity in Southeast Asia, including Thailand. Many countries in the region, including Thailand, are low- and middle-income countries (LMICs) and lack specific policies on multimorbidity prevention and intervention. While existing policies on chronic diseases can be useful, they may not fully address the complexities of multimorbidity. We will explore how current policies can inform the development of guidelines tailored to managing multimorbidity in Southeast Asia.

1.6 Anticipated contribution

- 1) In the context of Thailand's rapidly transforming health status, the results of this thesis will raise awareness and concern about multimorbidity, shifting existing research that only addresses a single disease to multimorbidity research.
- 2) This awareness will also provide Thai policymakers with crucial information, such as age patterns, disease clustering, and regional variations, to develop effective guidelines for the prevention and intervention of multimorbidity. This is particularly important as Thailand currently lacks policies related to the management of multimorbidity.

- 3) Apart from Thailand, other LMICs in Southeast Asia are also experiencing problems associated with ageing. The incidence of multimorbidity will increase with age. Therefore, the results of this study will also provide valuable information on multimorbidity for countries and regions with similar backgrounds to Thailand.

1.7 The research gap

Although multimorbidity has been increasingly studied, several important gaps remain, particularly in low- and middle-income countries (LMICs) such as Thailand. Most existing research focuses on high-income settings, leaving limited understanding of multimorbidity prevalence, disease clustering, geographic distribution, and mortality impact in LMICs [4, 25]. The context-specific associations between socio-economic factors, lifestyle behaviours, and multimorbidity remain poorly understood, and the interactions among different risk factors have not been comprehensively examined [1, 10]. Moreover, policy frameworks and healthcare strategies for preventing and managing multimorbidity in Southeast Asia are underdeveloped, and region-specific evidence is scarce.

This study addresses these gaps by leveraging data from the Thai Cohort Study, a large-scale longitudinal cohort, to provide detailed analyses of disease patterns, socio-demographic and lifestyle risk factors, spatial distribution, and mortality outcomes. By doing so, it not only enhances understanding of multimorbidity in Thailand but also generates evidence relevant for other LMICs facing similar health transitions, thereby informing public health strategies and policy development in the region.

1.8 Thesis structure

This thesis consists of 7 peer-reviewed journal articles (6 published and 1 accepted) which together address 6 research questions. At the beginning of each chapter, I summarise its contribution to the whole dissertation as well as the publication status and co-authors. In addition, there are unpublished introduction, literature review and discussion and conclusion chapters.

Chapter 1. Introduction: This chapter begins with a discussion of multimorbidity and the global health burden it poses. It then briefly describes the status of multimorbidity in

Thailand. The rest of the chapter describes the rationale, purpose and objectives of the study and finally introduces the expected contribution of the dissertation and the dissertation structure.

Chapter 2. Literature review: The chapter introduces the definitions, measurement methods, and clustering patterns of multimorbidity. The chapter also outlines the health burden of multimorbidity in the global context, the status of multi-morbidity in current Thailand in the background of health transition, and future research on multimorbidity in Thailand.

Chapter 3. Methodology: This chapter outlines the methods employed in the thesis. The analysis of disease burden, mortality, and geographic distribution of multimorbidity in Thailand was conducted using secondary data from the Thai Cohort Study (TCS). The methodologies described in Chapters 5 through 9 will be introduced here. Chapters 4 and 10, which are review-based and do not utilize TCS data, are also addressed to detail their respective methods.

Chapter 4. The systematic review of multimorbidity in Southeast Asia: This chapter serves as a foundational study on multimorbidity in Southeast Asia, setting the scene for the following analysis chapters using TCS data. It comprises a systematic review of multimorbidity in Southeast Asia, examining its prevalence and the link between educational attainment, a key socio-economic status (SES) factor, and multimorbidity. The study highlighted existing research, prevalence patterns, and the impact of SES on multimorbidity, offering insights and directions for future research in Thailand.

Chapter 5. The age and gender differences in patterns of multimorbidity in Thailand: This chapter aimed to examine the prevalence and patterns of multimorbidity across different age groups and genders in Thailand using TCS data. The findings provide insights for policymakers and researchers, supporting the development of targeted preventive and therapeutic strategies. By identifying common multimorbidity patterns, the research contributes to refining healthcare policies and improving clinical practices for managing complex health conditions in the Thai population.

Chapter 6. The health-risk factors of multimorbidity in Thailand: This article used TCS data to identify local risk factors for multimorbidity, providing insights into lifetime health risks and factors associated with multimorbidity in Thailand. By identifying at-risk

populations, the findings support targeted prevention efforts and inform public health strategies.

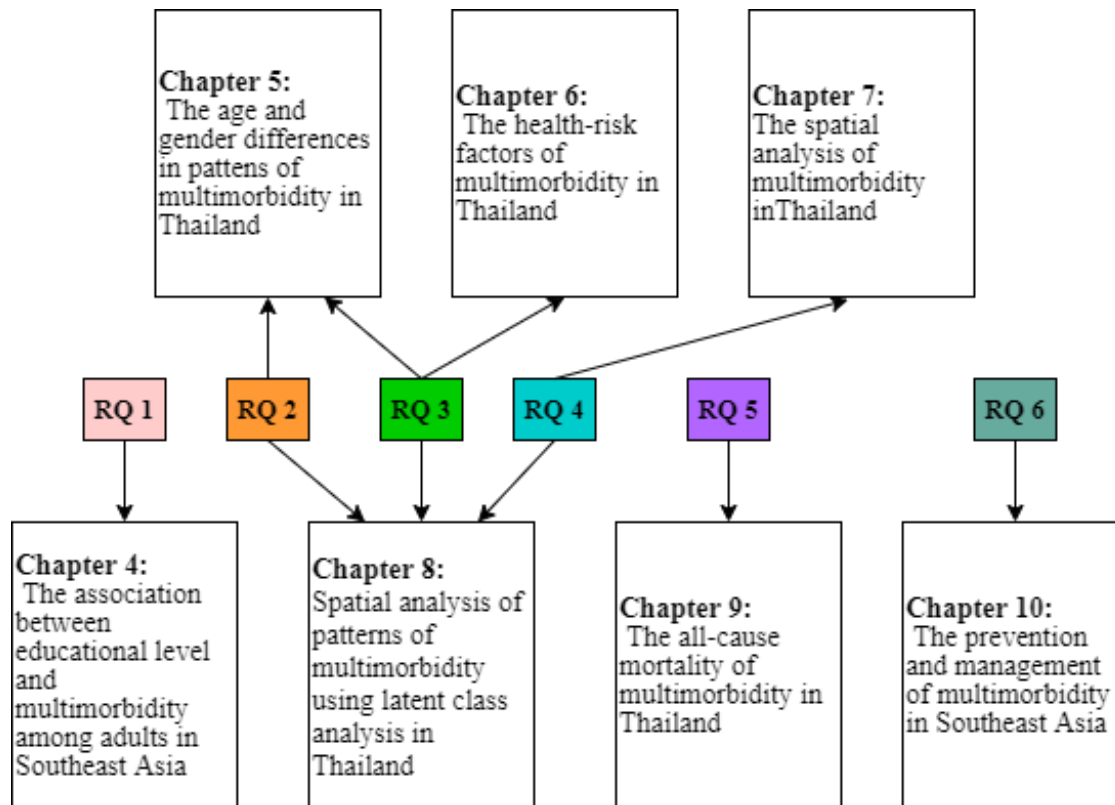
Chapter 7. The spatial analysis of multimorbidity in Thailand: This paper examines regional disparities in multimorbidity prevalence in Thailand, identifying high prevalence "hotspot" areas and clustering among diverse populations. Spatial analysis helps prioritise interventions, optimize healthcare services, and inform context-specific policies tailored to regional challenges.

Chapter 8. Spatial analysis of patterns of multimorbidity in the Thai Cohort Study using latent class analysis: This paper aims to explore the clustering of chronic conditions in the TCS using latent class analysis (LCA) to identify subpopulations based on co-occurrence patterns. LCA will describe these classes by sociodemographic and health behaviours. Spatial analysis will reveal geographic disparities in latent classes, highlighting high-prevalence areas and variations, supporting tailored prevention and management strategies.

Chapter 9. Multimorbidity and all-cause mortality in Thailand: This chapter examines the impact of multimorbidity and associated risk factors, including socio-demographics and health behaviours, on adult survival using TCS mortality data. Independent analyses will assess their individual and interactive effects on mortality risk. The findings aim to inform healthcare policy, resource allocation, and the design of targeted interventions to prevent multimorbidity and reduce mortality rates amidst demographic transitions.

Chapter 10. The prevention and management of multimorbidity in Southeast Asia: This paper provides a comprehensive review of multimorbidity prevention and management strategies in Southeast Asia. It explores preventive measures such as health literacy promotion, addressing social determinants, and stakeholder engagement, alongside strategies like strengthening primary healthcare, optimizing medication to prevent polypharmacy, and integrating digital health solutions. The goal is to offer detailed, evidence-based recommendations to guide future efforts in multimorbidity prevention and management in the region.

Chapter 11. Discussion and Conclusion: This chapter concludes by summarizing the thesis's key findings. It provides an overview of the results, followed by a detailed discussion of each research question. The strengths, limitations, public health implications, and scientific contributions of the dissertation are also addressed.



RQ: Research question

Figure 1 The results chapters connections to the research questions.

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Chapter 2 Literature Review

- Multimorbidity in Thailand: Disease burden, mortality, and geographic distribution

2.1 The overview of multimorbidity

Multimorbidity, also known as multiple chronic conditions, is generally defined as the presence of two or more chronic health conditions in a person at the same time. Due to increasing global aging, a transition in health burdens is occurring involving a shift from communicable to non-communicable diseases. This is then also leading to an increase in multimorbidity. Multimorbidity, is a condition that increases in incidence with age and is more common in people over 60 years of age. Multimorbidity is also now becoming a worldwide public health problem, especially in industrially mature developed countries because of their more severe aging [1]. These multimorbidity patterns typically include NCDs that common older adults are susceptible to, such as hypertension, diabetes and stroke. While the concern for multimorbidity is significantly higher in developed countries than in developing countries, multimorbidity has become an increasingly prominent issue as less developed regions move into aging societies, since the vast majority of the world's people over the age of 60 live in these places and where older adults are often poor as well as socially disadvantaged and do not have access to effective treatment if they develop multimorbidity [1, 2]. Currently, the prevalence of multimorbidity is higher in high-income countries (HICs) than in low- and middle-income countries (LMICs), at about 13-15% [3], and the magnitude of multimorbidity in LMICs is estimated at 10% to 11% [3, 4], which is predicted to rise in the coming years [3, 4].

However, it is worth noting that there are no standardised definitions, measures and patterns of multimorbidity [5-7]. Although it is generally accepted that two or more chronic diseases in one person at the same time is considered to be multimorbidity, other definitions of multimorbidity include having three or more diseases rather than two or more [5]. Simple counting of the number of conditions experienced by an individual is the most commonly used measure, but when it comes to disease severity and exploring the associated risks, weighted measures, including Charlson Comorbidity Index (CCI) and Elixhauser Comorbidity Index (ECI), could be more accurate and precise [5-7]. There are many different methods to clustering chronic conditions according to the purposes of research, and

commonly used ways include prevalence-based analysis, factor analysis and hierarchical clustering [1, 2, 5].

International organizations, such as WHO, as well as developed and developing countries are making guidelines and policies for the prevention and treatment of multimorbidity, usually through the primary health care sector [1, 2, 8-10]. Developed countries have well-established guidelines for the prevention and treatment of multimorbidity and emphasize the need for synergy across different sectors to address multimorbidity [4, 5]. With the outbreak of COVID-19, these countries have also added COVID-19 policies on how to prevent and treat patients with multimorbidity since COVID-19 is riskier for people who already have multimorbidity [11]. As for developing countries, although some countries such as Sri Lanka and Indonesia have some guidelines on the prevention and treatment of multimorbidity, these guidelines are not comprehensive [8, 9, 12]. Most less developed countries emphasise guidelines for the prevention and treatment of chronic single condition that make up multimorbidity. This often leads to underestimation of the complexity of multimorbidity, ineffective control of multimorbidity, and lack of appropriate care for patients with multimorbidity, which not only causes huge economic losses but also deteriorates their quality of life [1, 2].

This literature review systematically examines current research on multimorbidity, with a particular focus on Thailand, to inform the objectives of this study, which is to describe the prevalence and patterns of multimorbidity, to assess the influence of demographic, socioeconomic, and geographic factors and to evaluate existing health policies and interventions. The review begins by defining multimorbidity, distinguishing it from comorbidity, and summarising global patterns and trends. Special attention is given to the impact of population aging and health transitions on the rising prevalence of multimorbidity, highlighting variables that are well-established in the literature, such as age, lifestyle factors, and non-communicable diseases (NCDs), as well as those that remain under-investigated or controversial, such as the role of socioeconomic status (SES) in middle-income countries.

Subsequently, the review focuses on Thailand, synthesising evidence on its demographic characteristics, epidemiological transitions, and the current prevalence and patterns of multimorbidity. Each variable included in this thesis including age, gender, SES, geographic factors, and health-related behaviours, is critically appraised using prior studies, noting

inconsistencies and gaps in knowledge. Geographic disparities and environmental factors, such as population density and air pollution, are also considered underexplored.

Finally, the review evaluates existing policies and interventions for the prevention and management of multimorbidity, both globally and within Thailand. It highlights the limitations of current approaches, which predominantly target single NCDs rather than multimorbidity as a complex, multi-condition phenomenon. The review concludes by identifying critical gaps in knowledge and practice, demonstrating the novelty and rationale of the current study, and providing a foundation for future research and policy development tailored to Thailand's context.

2.2 What is multimorbidity?

2.2.1 What the is definition of the multimorbidity?

The earliest appearance of the concept of multimorbidity dates back to the 1970s. Before this, only the concept of “comorbidity” proposed by Feinstein was used to describe multi- and comorbidity [5, 6]. With the increased use of the term “multimorbidity” from the 1970s, definitions of multimorbidity and comorbidity became blurred and were often used interchangeably. In 1996, van den Akker et al. suggested clear definitions for both terms. Comorbidity, according to Feinstein, refers to “any significant additional entity that exists or may occur in the clinical course of the patient with the subject's disease,” whereas multimorbidity is defined as multiple chronic or acute illnesses occurring together in one person [5-7]. The major difference is that comorbidity emphasizes a primary disease-causing secondary condition, while multimorbidity does not [5, 6].

The current definition of multimorbidity, “the co-existence of two or more chronic conditions in a single individual,” was proposed by Boyd and Fortin in 2010, simplifying van den Akker et al.'s concept. This definition emphasizes chronicity and the absence of primary-secondary distinction, distinguishing it from comorbidity [6, 7], and has been widely adopted, including by the WHO [2, 5]. For the purpose of this study, we adopt this definition because it aligns with the Thai Cohort Study data and facilitates comparability with previous studies in Thailand and other LMICs.

Other definitions exist, such as complex multimorbidity (three or more chronic diseases in one individual) and definitions by the Academy of Medical Sciences, which include physical,

mental, and long-term infectious conditions [2, 5, 6]. These variations reflect ongoing debates in the literature about which conditions should be included, illustrating an area of uncertainty and methodological heterogeneity that this study addresses.

There are multiple ways to measure multimorbidity. Simple counting of chronic diseases is the most common method for estimating prevalence [5, 13], while weighted indices such as the Charlson Comorbidity Index (CCI) [14-16] or Elixhauser Comorbidity Index (ECI) [15, 16] may better assess health risks. In this study, we primarily use simple counting to describe prevalence and patterns of multimorbidity in the Thai population, as it is appropriate for population-level analyses and comparison across subgroups. Weighted indices, while informative for individual risk assessment, are not the primary focus here.

Changing definitions and measurement methods add complexity to treatment and management [17, 18]. For example, expanding the definition to three or more conditions can identify higher-need patients [18-20], and weighted versus simple counting methods may yield different results [19, 20]. These methodological choices highlight an area of uncertainty and variability in the literature, which this thesis addresses by explicitly stating the chosen definition and measurement aligned with population-level analysis.

2.2.2 The patterns of multimorbidity

There is now a commonly used definition of multimorbidity from the WHO, but the complexity of multimorbidity patterns makes it difficult to reach a consensus on a simple definition. The current definition also does not clearly distinguish between multimorbidity and multi-form comorbidity [21-23]. Comorbidity is defined as a condition in which one disease predisposes to another; the pattern focuses on whether patients with a particular condition are more likely to develop another than the general population. For example, hypertension, cardiovascular diseases (CVDs), kidney disease, and obesity are comorbidities of diabetes, meaning diabetes is a predisposing factor, and patients with diabetes are more likely to suffer from these conditions [24]. However, patterns of comorbidity can sometimes involve coexisting conditions without an obvious causal relationship, which can be easily confused with multimorbidity. For instance, Abidin et al. defined comorbidity as the coexistence of at least one psychiatric disorder and one physical disorder, without specifying the chronological order of occurrence [25].

Although most conditions associated with multimorbidity are non-communicable diseases (NCDs), some infectious diseases, such as tuberculosis (TB) and HIV/AIDS, can also be included in definitions of multimorbidity [22, 26]. These patterns can be easily confused with comorbidities; for example, diabetes complicated by TB may be considered comorbidity rather than multimorbidity [27]. Patterns of mental-physical or psychosomatic multimorbidity also exist, where psychiatric disorders co-occur with physical illnesses [28, 29]. Mental and physical health are closely interrelated, and patients with psychosomatic multimorbidity face a heavy symptom and treatment burden, reduced quality of life, and impaired prognosis [30]. Psychiatric disorders in psychosomatic multimorbidity often include bipolar disorder, schizophrenia, and alcohol dependence, while other patterns may consist of multiple psychiatric disorders, typically classified under NCD multimorbidity [12, 31]. Other common patterns include cardiometabolic multimorbidity and musculoskeletal disorders [22].

A critical challenge is how to systematically compare chronic conditions within multimorbidity rather than relying solely on empirical grouping [5]. There are no clear or uniform norms for clustering chronic conditions, which is necessary to determine multimorbidity patterns. Common methods include prevalence-based analysis, factor analysis, and hierarchical clustering [5, 32, 33].

Prevalence-based analysis is widely used in cross-sectional studies to describe the coexistence and distribution of multimorbidity, helping policymakers and researchers understand the most common disease combinations [5, 32]. Factor analysis and hierarchical clustering can provide a more nuanced understanding. Factor analysis identifies underlying factors contributing to observed relationships between chronic conditions, while hierarchical clustering groups diseases based on similarity without assuming underlying factors [33, 34]. Prevalence-based analyses allow intuitive identification of common clusters, such as CVD clusters, useful in prevention and treatment planning [5, 32]. Factor analysis can suggest comprehensive treatment strategies for etiological sets, e.g., hypertension, diabetes, and high cholesterol [33, 34], whereas hierarchical clustering can identify patient groups at higher risk for specific conditions, guiding targeted preventive measures [33, 34]. Latent class analysis (LCA) is another method, uncovering latent clusters within chronic conditions and facilitating understanding of underlying disease structures [5, 33, 34]. Model fit is typically evaluated using AIC and BIC, with smaller values indicating better fit. LCA can, for example, identify

sub-patterns of CVDs, such as hypertension or hyperglycaemia sub-patterns, classifying individuals into distinct statuses [5, 33, 34].

Although no unified definition of multimorbidity patterns exists, they can be distinguished from comorbidity models based on study population. Comorbidity studies focus on patients with a specific primary disease, while multimorbidity studies consider individuals with multiple conditions without a primary-secondary hierarchy [6, 35]. Distinguishing between comorbidity and multimorbidity clarifies disease causation, which is essential for research and informs prevention and treatment. However, in some cases, it can be challenging to determine whether coexisting conditions represent comorbidity or multimorbidity. For example, an unhealthy diet may lead to both diabetes and CVD, yet diabetes can also independently induce CVD [6, 35].

In summary, patterns of multimorbidity are complex and heterogeneous, with substantial variability between studies, making it difficult to identify consistent patterns [36]. Currently, there is no widely accepted criterion for selecting chronic conditions, and studies often include common or highly prevalent conditions [19, 36]. This limitation can reduce the generalizability of multimorbidity research and highlights the need for systematic, standardized approaches in future studies.

2.3 The health burden of multimorbidity in the world

2.3.1 Global aging

With industrialization, labour productivity has increased, leading to social progress and improvements in vaccine policies, sanitation, and diet, which collectively reduced young-age mortality, increased life expectancy, and lowered birth rates [37-39]. Consequently, populations are living longer, resulting in an aging society. In the 21st century, the global rate of aging is accelerating significantly [37-39]. Between 2020 and 2030, the population aged 60 and over is projected to grow from 1 billion (around 13% of the global population) to 1.4 billion (about 16%) [40]. The proportion in developed regions will approach 30%, compared with around 14% in less developed regions. For the first time in history, older adults may outnumber children under 5. Aging societies are currently more prevalent in high-income countries (HICs), likely due to earlier industrialization, but the absolute number of older adults will increase fastest in developing countries, from 650 million in 2017 to 1.7 billion by

2050, while in developed countries it will rise from 310 million to 427 million. Nearly 80% of the world's older population will live in less developed countries [37].

Population aging is a major driver of multimorbidity, yet its impact is modulated by national income, infrastructure, sanitation, and healthcare capacity, which are often lower in developing countries, exposing older adults to additional health challenges [2, 39]. This highlights an important knowledge gap, which means that while aging is a well-established risk factor, its interaction with resource constraints in LMICs remains under-investigated.

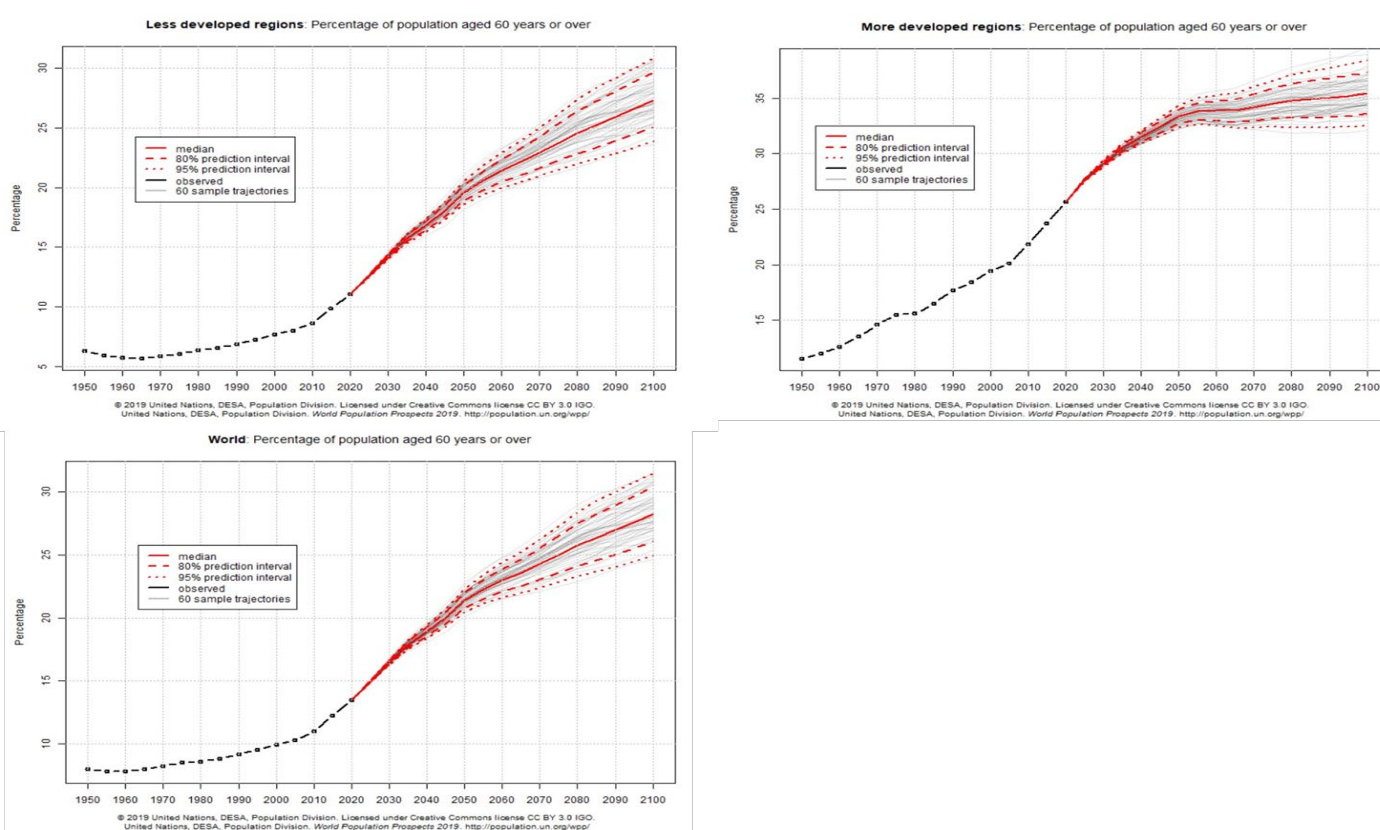


Figure 1. The percentage of population aged 60 years or over in less developed regions, more developed regions, and the world [40].

2.3.2 The health transition in the world

The health transition, coined by John Caldwell in the early 1990s, combines demographic transition: “from high fertility and mortality to low fertility and mortality in modern societies” and epidemiological transition: “from infectious to chronic diseases alongside demographic, economic, and societal changes” [41-43]. This concept provides a framework for understanding shifts in global health patterns [41].

Historically, health transition has passed through three phases: ancient plagues and famines, the receding pandemics of the mid-19th century, and the current phase dominated by chronic disease [41, 42]. Most countries are in the third stage, while some less developed regions remain in the first or second stages. Effective control of infectious diseases (e.g., malaria) has been achieved through advances in medicine and public health measures such as insecticide-treated nets in Southeast Asia [44]. Meanwhile, the incidence of non-communicable diseases (NCDs) has risen due to aging and lifestyle changes linked to industrialization, including high-calorie diets and physical inactivity [42, 44].

Although healthcare improvements reduce mortality, the incidence of chronic diseases is less controllable due to social, cultural, and environmental factors [42]. Globalization and rapid urbanization have accelerated lifestyle changes in developing countries, contributing to higher NCD prevalence [3, 4, 44]. This ongoing health transition is particularly pronounced in LMICs, where epidemiological evidence remains limited. Consequently, understanding the links between lifestyle, aging, and multimorbidity in LMIC contexts is essential for targeted public health interventions.

2.3.3 *The current status of multimorbidity in the world*

As a result of this health transition, the prevalence of multimorbidity is increasing. With population aging and lifestyle change there is a greater risk of cumulative incidence of chronic conditions in individuals [45, 46]. The prevalence of multimorbidity is currently higher in high-income countries (HICs) than in low- and middle-income countries (LMICs), estimated at approximately 13-15% [3, 4]. In contrast, the prevalence in LMICs is around 10–11% [3, 4, 45, 46] and is expected to increase in the coming years. However, there is more concern about multimorbidity in HICs than in LMICs, which may be related to the earlier entry into an aging society in developed countries [2]. At this stage, research on multimorbidity is also concentrated in developed countries, while in developing countries the focus is more on single diseases but is also moving to multimorbidity [1].

Among HICs, common multimorbidity may include CVD and cerebrovascular accident (CVA), diabetes, chronic kidney disease, and psychological disorders [1, 2]. However, in addition to these non-communicable chronic diseases in LMICs, chronic disease “clusters” may more often involve long-term chronic infectious diseases such as HIV and TB [2]. Meanwhile, the distinctions in multimorbidity due to gender differences are also more

pronounced in these developing countries. Males are more likely to suffer from cardiometabolic multimorbidity, while women have psychological and physical multimorbidity such as hypertension, which may be because of the lower social status of females [1, 2]. Since women with lower social status may face economic pressure, family responsibilities, and social discrimination, increasing the risk of both psychological issues (such as depression) and physical problems (such as hypertension). For example, depression can worsen hypertension, while the chronic management stress of hypertension can exacerbate depression, creating a vicious cycle [1, 2].

Factors influencing the health transition can also have an impact on the prevalence of multimorbidity. Thus, the prevalence of multimorbidity is also impacted by lifestyles, dietary habits, living environment and socioeconomic factors such as education and income [47]. In general, in most middle- and upper-income countries, people with low SES are more likely to suffer from multimorbidity because they are unable to establish good living and eating habits (nutrition transition and economic change meaning processed foods are cheaper than healthier foods, and more convenient) and face great stress from their living circumstance [48]. However, for some low-income countries, people with high SES are more exposed to western living and eating habits, which leads to higher SES being more likely to suffer from multimorbidity [48].

For people with low SES with multimorbidity, due to the complexity of symptoms and the higher treatment requirements compared to single diseases, patients with multimorbidity often do not receive cost-effective treatment, thus increasing their financial and medical burden, leading to a further decline in quality of life and causing greater damage to physical and mental health [39, 49]. In many developing countries, where the majority of people with low SES are concentrated, health care systems face multiple challenges, including limited access, high out-of-pocket costs, inadequate prevention and screening policies, poor continuity of care, and underdeveloped health information systems. Therefore, it is imperative to establish more comprehensive and integrated health care systems to address the needs of multimorbidity in these regions [31, 39, 49]. These challenges highlight gaps in health system preparedness for multimorbidity in LMICs, which the current study seeks to address by providing population-level evidence from Thailand.

2.4 Policies and guidelines for multimorbidity

An increasing number of countries are aware of the seriousness of multimorbidity and have introduced a series of policies targeting its effective control, ranging from international to national levels [2, 10]. For instance, the World Health Organization (WHO) released a report on multimorbidity in 2016, analysing the burden of multimorbidity and describing interventions to strengthen primary health care. The report emphasizes increasing universal health coverage, reducing the “inverse care law” where healthcare availability is inversely proportional to demand, addressing inequalities in healthcare resources and systems, and improving access for the general population, especially for people with low SES [1, 49].

Furthermore, healthcare systems are encouraged to design services that prevent and delay multimorbidity. This includes training primary care providers as “expert general practitioners” and developing clinical guidelines specific to multimorbidity, rather than relying solely on single-disease guidelines. Safe and effective care should be individualized according to each patient’s needs and realities [1].

In HICs, multimorbidity has become the norm. For example, in Australia, around 20% of the population suffers from multimorbidity [11]. Most care is provided by general practitioners and primary care health professionals, who must manage polypharmacy and multiple therapies, balancing treatment effectiveness while minimizing risks such as over-prescription and drug interactions [50]. Additionally, the majority of patients with multimorbidity are over 60 years old. Unlike home-based care models in developing countries, older adults in HICs are often concentrated in nursing homes, prompting these countries to strengthen nursing home capacity, including staffing and infrastructure improvements [1, 33]. The COVID-19 pandemic has further highlighted the vulnerability of patients with multimorbidity, leading to targeted measures such as vaccination campaigns, hygiene protocols, and social distancing guidance [11]. Improving coordination and communication between different sectors of the healthcare system is considered essential for effective prevention, rational treatment, and quality care for multimorbid patients [2].

Despite these advancements in HICs, knowledge gaps remain in LMICs. Developed countries such as the UK and Canada have conducted epidemiological studies on multimorbidity, healthcare utilization, and SES impacts, whereas in Southeast Asia and other developing regions, similar information is scarce [2, 9]. Policies in less developed regions often focus on

single chronic diseases, such as CVD, diabetes, or HIV, rather than multimorbidity [2, 9]. Interventions include promoting healthy behaviours (quitting smoking and alcohol, increasing physical activity), improving SES (protecting women's education and work rights, raising wages), and enhancing the living environment (building parks for exercise and relaxation) [2, 9].

In countries like Sri Lanka and Indonesia, primary healthcare systems, such as community hospitals, play a role in preventing and treating multiple chronic diseases [8, 12, 31]. However, most LMICs still lack policies specifically targeting multimorbidity, creating a gap in prevention and management strategies. Relying solely on single-disease guidelines ignores the complexity of multimorbidity, often resulting in ineffective treatment, increased economic burden, and reduced quality of life [2, 49]. Given the growing burden of multimorbidity and its interaction with socioeconomic factors, further research is urgently needed in developing countries to inform targeted interventions and policies [49, 51].

2.5 Multimorbidity in Thailand

2.5.1 Demographics of Thailand

Thailand is a constitutional monarchy located in Southeast Asia, bordered by Burma to the north, Laos to the west, Cambodia to the southeast, and Malaysia to the south [45, 52]. It covers an area of about 513,000 square kilometres and had a population of nearly 70 million in 2021 [53].

Population aging was originally a phenomenon observed in developed industrial countries. However, due to globalization, improvements in living standards, and advances in medical technology worldwide, aging is now also occurring in Thailand and some other middle-income developing countries [54]. Since the 1990s, Thai society has been progressively aging. Over the last decade, the number of people over 65 years old has increased by an average of 280,000–300,000 per year. Currently, the population over 65 exceeds 9 million, accounting for approximately 13% of the total population [54]. According to United Nations standards, Thailand has entered an aging society [53, 54]. It is estimated that Thailand's elderly population will continue to rise over the next 20 years, reaching around 30% of people aged 60–65 by 2040 (see Figure 2) [40, 53]. Similar to high-income countries, the direct causes of Thailand's aging population are low birth and death rates in recent years, combined

with increased life expectancy. Since entering the aging phase, the birth rate has dropped by half (from 19 to about 10 births per 1,000 people), while the death rate has remained low (6–7 deaths per 1,000 persons), and life expectancy has increased by almost 8 years (from 69 to 77 years) [53].

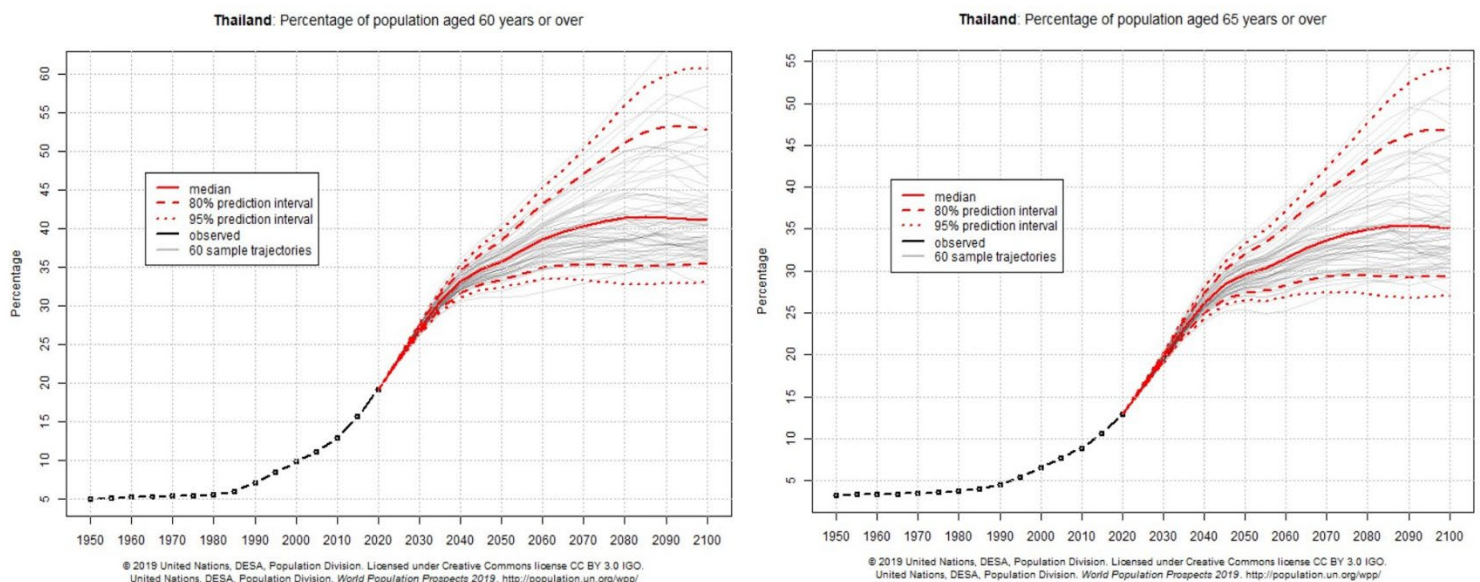


Figure 2. The percentage of population aged 60 years or over and aged 65 years or over Thailand [40].

As in other developing countries, the current model of senior care in Thailand remains largely family oriented. However, as the economy and society evolve, the traditional extended family is gradually being replaced by the two-generation nuclear family model. Increasingly, young people leave their parents to live independently after starting a family [59]. With rising work pressures and financial burdens, it is becoming more difficult for children to support their parents [55].

Furthermore, the lack of government welfare measures for senior care is increasingly apparent. The number of government-funded nursing homes is limited and cannot accommodate many elderly people. Although the government has encouraged religious groups to participate in the welfare sector, the outcomes have been modest [55, 56]. As the population ages, common aging-related diseases, such as Alzheimer's disease, are becoming more prevalent [55, 57]. The limited level of free public healthcare cannot fully meet the

needs of elderly patients, prompting many to seek more efficient, higher-level private medical care, which inevitably increases the financial burden on families [57].

2.5.2 Health transition in Thailand

Over the past half-century, Thailand has undergone significant social and economic transitions. These include increases in life expectancy at birth, declines in total fertility and infant mortality rates, and a shift in the economic structure from agriculture to industry, with the industrial sector outpacing agricultural growth [52].

These economic and demographic shifts have contributed to epidemiological and nutritional transitions, resulting in significant changes in health. Although rice remains the main source of calories and protein, the consumption of animal protein and fat has increased year by year, reflecting a gradual adoption of Western diets, while sugar consumption has risen significantly [52, 58, 41]. For example, between 1960 and the mid-1990s, rice consumption decreased by about one-third, while meat consumption increased fivefold, fat consumption increased 2.5 times, and sugar consumption rose dramatically from 0.2 g to 13.7 g, a 65-fold increase [52]. This increased intake of sugar and fat has contributed to the rising incidence of NCDs. From 1990 to 2019, stroke and ischemic heart disease overtook infectious diseases such as HIV as the leading causes of death in Thailand (see Figure 3) [59]. Between 2005 and 2019, disability-adjusted life years (DALY) losses due to stroke increased by approximately 100,000, and losses due to ischemic heart disease increased by about 105,000 [60]. As shown in Figure 4, DALY losses due to NCDs rank near the top among all conditions. In contrast, in the 1960s, the leading causes of death in Thailand were diarrhea and malaria [52, 59].



Figure 3. The causes of death in Thailand in 1990 and 2019 [59].



Figure 4. The DALY (Disability-Adjusted Life Year) losses of conditions in Thailand in 1990 and 2019 [59].

These infectious diseases remain present in Thailand but have declined rapidly, likely due to increased public health awareness and effective government policies, such as improvements in living environments and water quality [44]. As living standards have improved, mortality from infectious diseases has decreased, life expectancy has increased, and NCDs have become the leading causes of death [42, 44]. Risk factors for mortality in Thailand further reflect this shift (see Figure 5), with metabolic risks rising from outside the top five in the 1990s to within the top five in 2019 [59]. Dietary patterns strongly influence metabolic risks, such as high blood pressure and high blood glucose, which directly contribute to NCDs.

Currently, more than 200,000 people over 65 are affected by NCDs each year, and this number continues to rise [53].

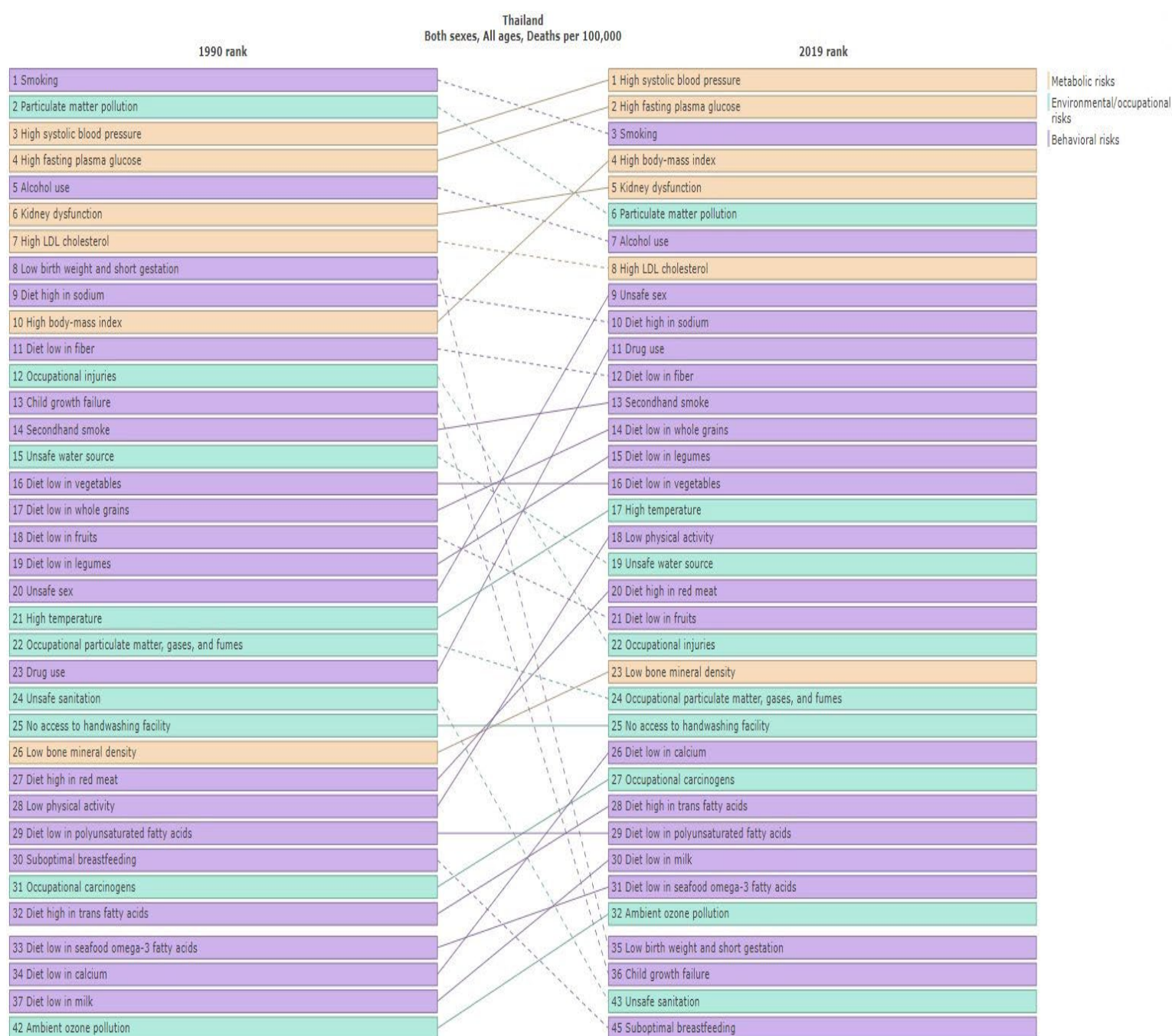


Figure 5. The risks of death in Thailand in 1990 and 2019 [59].

2.5.3 The trend of multimorbidity in Thailand

According to current studies, the prevalence of multimorbidity in Thailand is around 10%, slightly lower than in high-income countries (HICs) and similar to other developing countries

[61]. Aging is the most important risk factor for multimorbidity, and data show that older people are more likely to suffer from multimorbidity than younger people, particularly those over 55-60 years of age, with around 25% of this population affected [47, 61]. As people age, they may also adopt unhealthy behaviours, such as tobacco use, physical inactivity, and excessive alcohol consumption. Similar to other non-communicable diseases (NCDs), these behaviours contribute to an increased incidence of multimorbidity among Thais [47, 57].

In Thailand, the most common patterns of multimorbidity include diabetes, stroke, hypertension, and other cardiovascular diseases. Notably, multimorbidity combined with mental illness is becoming increasingly prevalent, similar to trends observed in other Asian countries such as China and Indonesia [23, 60]. This may be related to rising societal pressure and stress, and improved measurement of mental health in Thailand may also contribute to better detection [23, 60, 61].

An interesting observation is the association between socioeconomic status (SES) and multimorbidity. In some LMICs, including China, and in HICs, people of low SES are more likely to suffer from multimorbidity [44]. However, in Thailand, wealthier individuals appear more likely to develop multimorbidity than poorer individuals [61]. A similar pattern is seen in Bangladesh [62]. This phenomenon may be partly due to the limited research on multimorbidity in Thailand and the unequal distribution of medical and educational resources, meaning people with higher SES may have better health literacy and greater access to medical facilities, allowing them to be diagnosed more readily [62].

These findings highlight gaps in understanding the socioeconomic determinants of multimorbidity in Thailand and indicate a need for further investigation, particularly regarding how SES interacts with health behaviours and access to care.

2.5.4 Policies of the prevention and management of multimorbidity in Thailand

Currently, there are few guidelines in Thailand specifically addressing multimorbidity. Most policies are derived from the prevention and management of individual NCDs [53, 63].

Thailand has a universal health coverage system that allows the poor to receive free treatment. Similar to many other countries, multimorbidity is primarily diagnosed and managed through the primary healthcare system [50, 60].

Preventive approaches targeting chronic diseases are also applied to multimorbidity. For example, people are encouraged to exercise regularly and establish healthy dietary habits. Policy measures aim to improve the living environment and reduce harmful exposures, such as tobacco and sugar, through taxation (e.g., beverages containing more than 6% sugar) [61, 64]. HIV, a prevalent chronic condition in Thailand, is often accompanied by other chronic diseases. Prevention strategies for HIV include community and school-based interventions, such as sex education to raise awareness of HIV risks [65].

Patient-centred care, medication management to control polypharmacy, and digital health are also gaining attention [66-68]. However, most of these approaches remain at the policy or research stage, with only a few implemented in practice [66, 67].

Given the increasing prevalence and complexity of multimorbidity, including its course, pharmacotherapy, care, prevention, and management, it is no longer appropriate to address multimorbidity solely from a single-disease perspective [5, 69]. Thailand urgently needs dedicated policies and guidelines for the prevention and management of multimorbidity. This gap underscores the importance of developing context-specific interventions and integrated care models tailored to multimorbid patients.

2.6 Further research of multimorbidity in Thailand

Research on multimorbidity in Thailand is still immature and many questions remain to be addressed. Further research should focus on the prevalence of multimorbidity, its incidence, mortality, associated risk or protective factors, and geographic factors [47]. By analysing these aspects, elements contributing to the prevalence and incidence of multimorbidity can be identified, and appropriate recommendations can be provided for establishing improved guidelines for the prevention, treatment, and care of multimorbidity in Thailand [61].

In addition, the systematic review of the association between education and multimorbidity in Southeast Asia provides contextual information on the role of socioeconomic factors, especially education, in influencing multimorbidity. This review serves as background to justify including SES, education, and related lifestyle factors in further research in Thailand.

Factors associated with multimorbidity in future research could be divided into several categories. The first category is demographic factors. Gender, age, marital status, and residence may influence the prevalence of multimorbidity [44, 57]. Although some studies

have shown that women in Thailand are more likely to develop multimorbidity, it is still inconclusive whether gender directly affects risk [61]. Aging is consistently identified as one of the most important factors influencing multimorbidity [38].

Some studies have suggested that single individuals are less susceptible to multimorbidity in Thailand, but this finding is not consistent across studies and conflicts with observations in other countries where marriage reduces multimorbidity prevalence. Therefore, further research is needed [61]. Place of residence, including urban and rural areas as well as different cities and regions, directly influences the living environment, which may in turn affect multimorbidity [47, 52, 60]. Spatial analysis can help summarise and clarify these associations.

The second category is SES, including factors such as income and education. The relationship between multimorbidity and SES is complex. In HICs, a negative (inverse) relationship has often been observed [43]. However, studies in some LMICs, including Thailand, have found a positive relationship between SES and multimorbidity [61, 64]. Contradictory findings have also been observed for education and income factors. It is widely believed that people with low SES are more vulnerable to multimorbidity, due to limited health knowledge and difficulty affording nutritious food, leading to poorer health [70, 71].

Additionally, their inability to afford high-cost medical care after developing multimorbidity can further deteriorate their health. However, few studies in developing countries have investigated multimorbidity in depth, with most research still focused on single diseases. Although aging is increasing in LMICs, the proportion of elderly populations remains relatively low compared to developed countries [37]. This has resulted in a lack of longitudinal studies on SES and multimorbidity in LMICs such as Thailand [61].

The lack of research may contribute to the observed conclusion that higher SES increases the odds of multimorbidity. Furthermore, in developing countries, higher SES is often associated with sedentary lifestyles, which may increase multimorbidity risk. People with higher SES also have better access to medical care and health knowledge, making them more likely to be diagnosed with chronic diseases [62]. The relationship between SES and multimorbidity therefore requires more in-depth investigation, especially longitudinal studies in Thailand.

The third category is health conditions. People with chronic diseases, such as obesity, diabetes, and CVD/CVA, are at higher risk for multimorbidity, as shown in studies in

Thailand [31]. This may reflect comorbidity of these diseases. Nevertheless, multimorbidity and comorbidity are distinct concepts and must be clearly distinguished in research [5, 69].

Currently, there is no uniform pattern for measuring multimorbidity in most studies. The most common approach is to select common or highly prevalent diseases for inclusion. Some studies include psychological disorders, while others include chronic infectious diseases, leading to non-comparable results across studies [22]. Therefore, it is crucial to clarify the definition and pattern of multimorbidity within the same series of studies.

Health-related behaviours form the fourth category. Many studies in other countries have shown that behaviours influencing chronic disease also impact multimorbidity. Smoking, alcohol consumption, physical inactivity, and diets high in oil, salt, and sugar may contribute to multimorbidity, particularly among the elderly [47, 61]. However, such studies are rare in Thailand, and although similar trends may exist, health behaviours vary due to social, economic, and cultural differences. For instance, rice is the staple food in Thailand, differing from Western countries [52]. Cultural factors unique to Thailand may also influence behaviours affecting multimorbidity prevalence [58, 61]. Therefore, further research is needed to investigate health-related behaviours in the Thai context.

Moreover, to better understand the geographical and environmental factors affecting multimorbidity, such as air pollution and population density, spatial analysis of multimorbidity prevalence in Thailand is imperative [72-74]. Prevalence may vary between locations and populations, and regional differences can influence multimorbidity distribution [59, 73]. For example, air pollution can contribute to multimorbidity [74], and population density, as an SES factor, may impact prevalence [5, 48]. Understanding spatial distribution is essential for identifying high-prevalence areas, assessing environmental risk factors, and tailoring interventions [72-74].

Individuals with multimorbidity have higher mortality, which is about 1.5 times that of healthy populations [5, 75]. Yet, the impact of factors such as SES and health behaviours on multimorbidity-related mortality remains understudied [76, 77]. In LMICs, such studies are particularly scarce despite these countries having the majority of the aging population [5, 75]. Therefore, exploring mortality and related risk factors among multimorbid patients is critical in Thailand.

Although multimorbidity prevalence is rising in Thailand and other Southeast Asian countries, well-established prevention and management measures are lacking [5, 61]. Most approaches are derived from NCD management, with no distinct model for multimorbidity [5, 78]. Future research can build on existing strategies and combine them with WHO-recommended approaches [1] and experiences from developed countries such as Australia [11] to explore practical multimorbidity management strategies, addressing the rising prevalence and improving population health.

Therefore, future research should aim to elucidate the prevalence of multimorbidity in Thailand and identify potential contributing factors. It should also provide valuable information for local governments to develop guidelines and policies for effective prevention, treatment, and care, reducing the burden of multimorbidity and improving health and quality of life.

2.7 Conclusion

The global health transition from communicable to non-communicable diseases has contributed to an increasing prevalence of multimorbidity, particularly among aging populations. While high-income countries have established guidelines for managing multimorbidity, LMICs, including Thailand, face challenges such as limited research and the lack of comprehensive guidelines. The absence of uniform standards for defining and measuring multimorbidity further complicates efforts to address this complex health issue. Multimorbidity is generally considered the presence of two or more chronic conditions simultaneously, but definitions and measurement approaches vary, ranging from simple counts to weighted indices such as the CCI and ECI. Common clustering methods include prevalence-based analyses, factor analyses, and hierarchical clustering. Comorbidity can also be confused with multimorbidity; unlike multimorbidity, comorbidity assumes a primary disease leading to secondary conditions.

In Thailand, studies indicate that the prevalence of multimorbidity is around 10%, slightly lower than in high-income countries but similar to other developing countries. Aging, lifestyle factors such as tobacco use, physical inactivity, and alcohol consumption, as well as common NCDs including diabetes, stroke, and hypertension, contribute to multimorbidity. Multimorbidity combined with mental illness is increasingly observed, reflecting broader

Asian trends. Socioeconomic patterns differ from some other LMICs, with higher SES groups more likely to report multimorbidity, possibly due to greater health literacy and better access to healthcare. While the broader Southeast Asian context has been reviewed in other chapters of this thesis, the focus here on Thailand highlights the unique national patterns and provides context for policy and practice considerations.

Understanding these factors is essential for informing policies and guidelines tailored to the Thai context, as well as LMICs more broadly, to facilitate effective prevention, treatment, and care for those affected by multimorbidity. Further research is needed to monitor trends, clarify risk factors, and guide interventions to address the growing burden of multimorbidity in Thailand and similar settings.

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Chapter 3 Methodology

This chapter outlines the methodological approaches used in this thesis. We employed a combination of literature review (Objective 1: To identify the regional prevalence of multimorbidity and the socio-economic factors driving it, with an emphasis on education in Southeast Asia), narrative review (Objective 4: To explore practical and comprehensive multimorbidity prevention and management policies and approaches suitable for Southeast Asian contexts by reviewing existing guidelines and strategies), and empirical data analysis using the Thai Cohort Study (TCS) (Objective 2: To understand the status of multimorbidity via TCS in Thailand, especially the a) disease clustering, b) risk factors and epidemiology, and c) spatial distribution; and Objective 3: To investigate the impact of multimorbidity and related health-risk factors, including socio-demographic characteristics and health behaviours, on adult survival by analysing the mortality data from the TCS).

The TCS provided secondary data for analysing disease burden, mortality, and geographic distribution of multimorbidity. Chapter 4 details the review methodology, Chapters 5-9 present empirical analyses, and Chapter 10 discusses policy implications.

3.1 The methods for Objective 1 – the Systematic review (Chapter 4)

The title of Chapter 4 is “The association between educational level and multimorbidity among adults in Southeast Asia: A systematic review” [1], which was applied the terms of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement [2]. Criteria for inclusion encompassed quantitative observational studies published between 1990 and 2021, reporting multimorbidity defined as two or more chronic conditions, and detailing associations with educational levels. Databases including Scopus, PubMed, and ProQuest were searched using specified terms. Human studies over 15 years old with available English abstracts were considered [1].

Two reviewers independently screened titles and abstracts, with disagreements resolved through discussion or consultation with a third reviewer. Full-text screening followed initial selection. Study quality was assessed using the Newcastle Ottawa Scale (NOS) for observational studies [3]. Articles with a quality score of four or above were retained. The

methodology had been published in PROSPERO with registered number ID: CRD42021259311.

Data extraction included study details, population characteristics, multimorbidity definition, prevalence of multimorbidity, educational attainment breakdown, and association results. Due to methodological heterogeneity, narrative synthesis was employed, with prevalence of multimorbidity calculated or categorized as "not available" where necessary [4]. Ratios of multimorbidity at different educational levels were extracted directly from the included studies.

3.2 The database

For Objectives 2 and 3, this thesis utilised data from the Thai Cohort Study (TCS), which provides a comprehensive longitudinal dataset for examining the burden, mortality, and geographic distribution of multimorbidity in Thailand. Details of the TCS, including its design, variables, sample characteristics, and ethical approval, are presented below.

3.2.1 Thai Cohort Study (TCS)

The Thai Cohort Study (TCS) was a large-scale population health research project that aimed to explore the lifestyle, health status, prevalence of chronic diseases and related factors of the Thai population in the context of the health transition in Thailand. This study began in 2005 and was conducted in collaboration with Sukhothai Thammathirat Open University (STOU) [5, 6]. The TCS addressed four main themes during the following years (2005-2009 and 2009-2013): examining the temporal evolution of health risk within the Thai population, both in terms of downstream and upstream factors; investigating variations in risk distributions and transitions among different subgroups; exploring the correlation between evolving multilevel risks and the occurrence of diseases or injuries; and identifying evidence-based interventions essential for substantially alleviating the preventable burden of emerging diseases in Thailand [5, 6].

The cohort study, the TCS, started in 2005 (baseline), with follow-up surveys in 2009 (midpoint) and 2013 (endpoint). At each wave, mailed questionnaires were sent to participants, so a total of three self-administered questionnaires were included in the study. The questionnaires consisted of seven sections: the participant's residence and personal life;

earnings and employment; well-being, injuries, and utilization of health services; social connections and quality of life; dietary habits and engagement in physical activities; use of tobacco, alcohol, and transportation; and details about the participant's family [5, 6]. These sections covered almost all relevant participant information, including sociodemographic data, indicators of health status, health behaviours, and history of physician-diagnosed disorders [7].

The variables used in this thesis were derived directly from these questionnaire sections. Specifically, sociodemographic characteristics (such as age, sex, marital status, education, income, and place of residence) were obtained from the residence and personal life and earnings and employment sections. Health status variables (including self-reported disorders) were extracted from the well-being, injuries, and utilization of health services section. Health behaviour variables (like diet, physical activity, smoking and alcohol consumption, and transportation use) were derived from the dietary habits and physical activities and use of tobacco, alcohol, and transportation sections. Social connections and quality of life were drawn from the social connections and quality of life section. These variables were selected because they represent common factors associated with chronic conditions and multimorbidity [8-10]. A detailed description of these variables, including their definitions, coding schemes, and measurement details, is provided in Table 1.

In addition, each participant in the TCS was asked to share their Citizen Identification Number (CID), a 13-digit unique identifier used by the Thai government [8, 9]. The CID lists of all TCS members are regularly checked against government death records maintained by the Thai Ministry of Interior, and the most recent death data available to us is for 2019 [10-12]. The full questionnaire (Baseline 2005 and Final 2013) and ethics approval documents are provided in the Appendix 2.

Table 1. Variables, questionnaire items, and coding of health-risk factors in the TCS

Domain	Variables	Questionnaire Items	Coding / Categories
Socio-demographic factors	Gender	Baseline 2005 A2/Final 2013 A1	Male = 1 (reference), Female = 2
	Age (years)	Baseline 2005 A1/Final 2013 A2	≤ 39 = 1 (reference), 40-59 = 2, ≥ 60 = 3
	Marital status	Baseline 2005 A8/Final 2013 A17 A18	Living with partner = 1 (reference), Single = 2

Domain	Variables	Questionnaire Items	Coding / Categories
	Geographic regions	Baseline 2005 Province/ Final 2013 Province	Bangkok = 1 (reference), Central = 2, North = 3, Northeast = 4, East = 5, South = 6
	Life course residence*	Baseline 2005 A14	RR = 1 (lifelong ruralites, reference), RU = 2 (urbanizers), UR = 3 (de-urbanizers), UU = 4 (urbanites)
	Personal monthly income (Baht)	Baseline 2005 B1/Final 2013 A14	≤7000 = 1 (reference), 7001-10000 = 2, 10001-20000 = 3, ≥20001 = 4
	Monthly household income (Baht)	Final 2013 A15	≤7000 = 0 (reference), 7001-10000 = 1, 10001-20000 = 2, ≥20001 = 3
	Educational levels	Baseline 2005 A6/Final 2013 A16	Junior school = 1 (reference), High school = 2, Diploma = 3, University = 4
Health conditions	Multimorbidity	Baseline 2005 C13/ Final 2013 F1	Baseline: No = 0 (reference), Yes = 1
Health behaviours/ Personal lifestyles	Dietary consumption	Baseline 2005 E1, E4, E5/Final 2013 D1, D2, D4, D9	Deep fried food, Instant food, Soft drinks, Fast food: less than once a month (reference) = 1, 1-3 times a month = 2, 1-2 times a week = 3, 3-6 times a week = 4, and daily or more = 5; Fruits/Vegetables/Sugar (serves/day)**: 0-4 = 1 (reference), 5-9 = 2, 10-14 = 3, ≥15 = 4
	Activity status	Baseline 2005 E6, E7, E8/Final 2013 D13, D14, D15	Weekly exercise:# 0-7 = 1 (reference), 8-14 = 2, ≥15 = 3; Housework: less than once a month (reference) = 1, 1-3 times a month = 2, 1-2 times a week = 3, 3-6 times a week = 4, and daily or more = 5; Sleeping: ≤ 6h = 2, 7-8h = 1 (reference), ≥ 9h = 3; Sedentary: ≤ 7h = 1 (reference), 8-12h = 2, ≥ 13h = 3
	Smoking status	Baseline 2005 F1/Final 2013 G1	Non-current = 1 (reference), Current = 2
	Drinking status	Baseline 2005 F6/Final 2013 G2	Never = 1 (reference), Ex-drinker = 2, Occasional social = 3, Current regular = 4

Life course residence*: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) [7, 11, 13, 14].

Fruits, Vegetables, Sugar (serves/day)**: The grouping of intake of fruits, vegetables and sugar would be consistent with that of previous articles [7, 11, 13, 14]

Weekly exercise#: there are three groups, namely “vigorous exercise over 20 minutes”, “moderate exercise over 20 minutes” and “walking for at least 10 minutes”. According to the International Physical Activity Questionnaire and the Australian Active Survey [7, 11, 13, 14], this study used the adjusted exercise weights to assess weekly physical activity: “2 × vigorous exercise + 1 × moderate exercise + 1 × number of walks per

week". The weekly exercise was divided into three groups: 0-7, 8-14 and ≥ 15 , which was consistent with the grouping of previous articles [7, 11, 13, 14].

Coding of categorical variables follows the reference and category information presented in the table.

Dietary, activity, smoking, and drinking variables were derived from the corresponding questionnaire sections (see Appendix for full questionnaire).

Variables were selected because they are common indicators associated with multimorbidity and chronic diseases.

3.2.2 *The study sample of TCS*

The questionnaires were sent to all enrolled students (around 200,000 people) at Sukhothai Thammathirat Open University (STOU) in 2005. The students who responded (around 45%) formed the baseline cohort study group (over 80,000 participants). As such a sample size calculation is not applicable to the TCS [5, 10].

The main aim of this study was to identify relationships between exposures and outcomes in the cohort (internal validity) rather than claiming that our results represent prevalence levels in the general Thai population (external validity) [5, 11, 12]. At the midpoint of TCS in 2008, there were around 52,000 members and at the endpoint, 42,785 participants were remaining the study. Most of the studies in the thesis was focused on the endpoint in 2013 [5, 11, 12].

3.2.3 *Strengthens and limitations of TCS*

The TCS possesses strengths in its substantial cohort size and the distribution of participants by gender, occupation, and geographic location. Moreover, the sample in this cohort was similar to the Thai population in these aspects of their median age, median income, region and ethnic diversity, but students in TCS had a lower mean age, better educated background and higher percentage of participants living in the urban place [5, 6, 10]. Additionally, the study's robust data collection encompasses diverse information, facilitating the monitoring of exposures at various levels and the construction of health risk models that incorporate additional pertinent details [5].

However, there were also some limitations of the TCS. First, using self-reported questionnaires to report information regarding health issues over the participants' life course may produce recall bias. However, according to the validation study of Papier et al. [12], a high degree of concordance between the self-reported collected disease data in the TCS and

the clinical assessments was revealed, which supported the reliability and accuracy of the reported data in TCS [12]. Additionally, the last data collection of the TCS was in 2013, about a decade ago, so social and demographic factors may also have changed over the years. And the participants in TCS were students from the Open University, their age distribution is generally younger and more educated than the Thai general population [5, 11]. Finally, the number of conditions included in the questionnaires differed between waves: the 2005 baseline survey covered a broader range of diseases, whereas the 2013 follow-up survey included fewer conditions [5, 11, 12]. This discrepancy may also pose limitations for conducting longitudinal analyses, as the definition of multimorbidity is not fully consistent across waves.

3.2.4 *Ethical approval*

All individuals provided informed written consent and were notified that they had the option to withdraw or decline participation in the study without any impact on their academic advancement. The Thai Cohort Study (TCS) received approval from the ethics committee of the Sukhothai Thammathirat Open University (STOU) Research and Development Institute, with protocol number 0522/10. Additionally, for the sub-sample analysis, we obtained approval from the Human Research Ethics Committee of the Australian National University, with protocol numbers 2004/344, 2009/570, and 2021/796 [10]. The questionnaires and other data collection instruments used in this study are documented in the Appendix 2.

3.3 The methods for Objective 2 – the Cross-sectional study (Chapters 5 to 8)

Objective 2 of this thesis aimed to examine the disease clustering, risk factors, and spatial distribution of multimorbidity in Thailand using the Thai Cohort Study (TCS) 2013 dataset. Chapters 5 to 8 present a series of cross-sectional analyses addressing these aspects from different perspectives: disease clustering with gender and age (Chapter 5), socio-demographic and lifestyle risk factors (Chapter 6), spatial distribution of multimorbidity (Chapter 7), and spatial patterns of multimorbidity based on latent class analysis (Chapter 8). The following sections summarise the methods used in each chapter.

3.3.1 The methods in Chapter 5 – answering Objective 2: a) disease clustering, and b) risk factors and epidemiology

Chapter 5's title is "Impact of age and gender differences in the prevalence and patterns of multimorbidity in Thai Cohort Study". This cross-sectional analysis encompassed 42,785 respondents from the 2013 final mailed-in questionnaire in the TCS. Data included age (categorized as ≤ 39 years, 40-59 years, and ≥ 60 years) and gender (male and female) [5, 10].

Respondents reported diagnoses for 11 chronic diseases (hyperlipidaemia, hypertension, ischemic heart disease and stroke, liver cancer, lung cancer, stomach cancer, colon-rectum cancer and breast cancer and kidney diseases), with obesity defined by body mass index (BMI) $> 25 \text{ kg/m}^2$ for Asian populations (total 12 chronic conditions) [13-15]. Multimorbidity was defined as the same individual having two or more of these 12 chronic conditions, with patterns identified based on prevalent clusters. Descriptive analyses elucidated the prevalence of multimorbidity, the proportion of participants with each chronic disease and the average number of chronic diseases among individuals, and the distribution of individuals assigned to different numbers of chronic diseases [15]. Prevalence-based analysis ranked common multimorbidity patterns, and chi-square tests examined the relationship between gender and/or age and the prevalence of these patterns. P for trend (p-trend) assessed associations between the prevalence of multiple chronic conditions and ages (median age of participants with these diseases in different age groups), and the distribution of number of chronic conditions and their prevalence. Significance was defined as $p < 0.05$, and STATA 16 and Excel 2016 generated statistical analyses [15].

3.3.2 The methods in Chapter 6 – answering Objective 2: b) risk factors and epidemiology

The title of Chapter 6 is "Association of socio-demographic and lifestyle factors with multimorbidity among adults in the Thai Cohort Study". The study is a cross-sectional study, which focuses on the 2013 questionnaire with 42,785 respondents. Multimorbidity, defined as having two or more chronic diseases simultaneously, included 11 diseases and one condition (obesity), which is same as the Chapter 5.

Health-risk factors were categorized into socio-demographic and lifestyle factors (see Table 1) [7, 11, 13, 14]. Statistical analysis, conducted using Stata 16.0, included calculating multimorbidity prevalence, χ^2 tests for differences, and logistic regression for associations

between health risk factors and the prevalence of multimorbidity. P for trend (p-trend) were used to test the linear trend. Stratified analysis by gender and multivariate logistic regression models were employed, adjusting for confounders. Significance was set at $p < 0.05$. See Table 1 for detailed information [7].

Table 2 Health-risk factors for multimorbidity in the TCS

Domain	Variables	Confounders
Socio-demographic factors	Gender: male (reference) or female	Age, marital status, geographic regions, life course residence, personal monthly income, monthly household income, educational levels, All factors of health behaviours.
	Age (years): ≤ 39 (reference) or 40-59 or ≥ 60	Gender, marital status, geographic regions, life course residence, personal monthly income, monthly household income, educational levels, All factors of health behaviours.
	Marital status: living with partner (reference) or single	Gender, age, geographic regions, life course residence, personal monthly income, monthly household income, educational levels, All factors of health behaviours.
	Geographic regions: Bangkok (reference) or Central or North or Northeast or East or South	Gender, age, marital status, life course residence, personal

	monthly income, monthly household income, educational levels, All factors of health behaviours.
Life course residence*: Rural-rural (lifelong ruralites, RR) (reference) or Rural-urban (urbanizers, RU) or Urban-rural (de-urbanizers, UR) or Urban-urban (urbanites, UU)	Gender, age, marital status, geographic regions, personal monthly income, monthly household income, educational levels, All factors of health behaviours.
Personal monthly income (baht): ≤ 7000 (reference) or 7001-10000 or 10001-20000 or ≥ 20001 (One US dollar were equivalent to around 35 Baht in 2013.)	Gender, age, marital status, geographic regions, life course residence, monthly household income, educational levels, All factors of health behaviours.
Monthly household income (baht): ≤ 7000 (reference) or 7001-10000 or 10001-20000 or ≥ 20001 (One US dollar were equivalent to around 35 Baht in 2013.)	Gender, age, marital status, geographic regions, life course residence, personal monthly income, educational levels, All factors of health behaviours.
Educational levels: junior school (reference) or high school or diploma or university	Gender, age, marital status, geographic regions, life course residence, personal monthly income, monthly household income,

Drinking status	occasional social or current regular	sleeping time, sedentary time.

Multimorbidity is defined as having ≥ 2 chronic conditions, including 11 diseases and obesity ($\text{BMI} > 25 \text{ kg/m}^2$). χ^2 tests were used for categorical comparisons; logistic regression models were applied for associations between risk factors and multimorbidity.

Variables listed include confounders adjusted in multivariate models.

The selection of variables is based on their relevance to multimorbidity and chronic disease risk.

Life course residence*: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) [7, 11, 13, 14].

Fruits, Vegetables, Sugar (serves/day)**: The grouping of intake of fruits, vegetables and sugar would be consistent with that of previous articles [7, 11, 13, 14].

Weekly exercise#: there are three groups, namely “vigorous exercise over 20 minutes”, “moderate exercise over 20 minutes” and “walking for at least 10 minutes”. According to the International Physical Activity Questionnaire and the Australian Active Survey [7, 11, 13, 14], this study used the adjusted exercise weights to assess weekly physical activity: “ $2 \times \text{vigorous exercise} + 1 \times \text{moderate exercise} + 1 \times \text{number of walks per week}$ ”. The weekly exercise was divided into three groups: 0-7, 8-14 and ≥ 15 , which was consistent with the grouping of previous articles [7, 11, 13, 14].

3.3.3 The methods in Chapter 7 – answering Objective 2: b) risk factors and epidemiology, and c) spatial distribution

The title in Chapter 7 is “The spatial analysis of multimorbidity in Thai Cohort Study”. This research was a cross-sectional investigation conducted in 2013, utilizing a questionnaire sent to 42,785 participants. The survey aimed to assess the distribution of multimorbidity based on district (second administrative level) and province (first administrative level) details based on respondents' home addresses [5]. The study focused on multimorbidity, which the definition is same as Chapter 5 and Chapter 6.

The study utilized spatial analysis techniques on data from the TCS, focusing on district and province levels. The spatial unit analysis included 76 provinces at the first administrative level in Thailand, excluding Bangkok, which is a special administrative area with 50 districts. The second administrative level comprised 878 districts (excluding the 50 in the capital). To

enhance accuracy, only provinces or districts with at least six TCS participants were considered [5].

Age-adjusted multimorbidity prevalence was calculated for each included district and province. Age adjustment was used to address differences in population structure and age distributions between the TCS and the general Thai population [16, 17]. The age structure of the Thai population, derived from Thai government sources, was used as the standard population for the age adjusted calculation [18]. Spatial autocorrelation (Global Moran's I), clustering (Getis-Ord General G), and hotspot analysis (Getis-Ord Gi*) were employed to assess potential clusters and high-risk areas of the crude and age-adjusted prevalence of multimorbidity at the study area [17, 19]. The conceptualization of spatial relationships in Getis-Ord Gi* statistic for Hotspot analysis applied the contiguity edges corners technique, which was suitable for irregularly shaped areas, considers neighbouring polygons as those touching each other, accounting for shared boundaries, nodes, or overlaps. Row standardization was employed to address variations in neighbour counts, creating proportional weights for more accurate computations [17, 19]. These prevalences and spatial analysis were used ArcGIS Pro 2.6 desktop (ESRI, Redlands, CA). The Ordinal logistic regression examined the impact of contextual factors on multimorbidity hotspots, considering population density, aging index, income, poverty line, and educational years [18-20]. Analysis was conducted using Stata statistical software (version 16.0).

3.3.4 The methods in Chapter 8 – answering Objective 2: a) disease clustering, b) risk factors and epidemiology, and c) spatial distribution

The title of Chapter 8 is “Spatial analysis of patterns of multimorbidity in the Thai Cohort Study using latent class analysis”, which also employed 42,785 members from the endpoint of TCS in 2013 [7]. The definition of multimorbidity is the same as Chapter 5, Chapter 6 and Chapter 7. The associated factors were consistent with the factors in Chapter 6.

Latent Class Analysis (LCA) identified multimorbidity patterns and their spatial distribution was then assessed. Several criteria including Bayesian Information Criterion (BIC) adjusted Bayesian Information Criterion (aBIC), Akaike Information Criterion (AIC), and Entropy Index were utilized to determine the optimal number of latent classes. Additionally, average posterior probabilities and likelihood ratio tests were employed to evaluate class membership

classification errors and the goodness of fit of different latent class models, respectively [21-23]. The associated factors were examined through adjusted multinomial logistic regression models (relative risk ratios, RRRs) [21]. To address missing values of indicators (chronic conditions) and variables, multiple imputation by chained equations (MICE) was used to produce 10 imputed datasets to minimise potential bias due to missing data [24, 25]. The results of the regression models in 10 imputed datasets were combined using Rubin's rules [24, 25]. The results were presented with 95% confidence intervals (CI), and the linear trend was assessed using P for trend (p-trend). Statistical significance was defined as a p-value less than 0.05. The sensitivity analysis which used the same models described earlier were re-applied to a subset of participants, consisting of individuals with valid values for all variables (n = 34903), which results would be compared with those from the imputed datasets [20, 24].

The spatial analysis mapped age-adjusted prevalence of multimorbidity patterns/latent classes of chronic conditions (the calculation of age-adjusted prevalence was similar to Chapter 7's calculation of age-adjusted prevalence of multimorbidity) across Thailand's provinces [17, 19, 20]. Employing Spatial Autocorrelation (Global Moran's I) and High/Low Clustering (Getis-Ord General G) clustering and high/low clustering were examined. Moreover, Anselin Local Moran's I and Hotspot analysis (Getis-Ord Gi*) identified clusters and outliers of prevalence and high and low prevalence in the provinces in Thailand, respectively. The contiguity edges corners technique was utilized to conceptualize spatial connections [17, 19, 20]. Additionally, row standardization was applied to generate proportional weights to mitigate variations in neighbour counts among features [17, 19].

3.4 The methods for Objective 3 – the Survival analysis (Chapter 9)

The Chapter 9's title is "The impact of multimorbidity on all-cause mortality: A longitudinal study of 87,151 Thai adults" [10]. A comprehensive health questionnaire was mailed to all students in 2005 and 87,151 people (age range: 15-87 years) responded. Mortality data, collected through the Ministry of Interior records, indicated 1,958 deaths from March 2005 to December 2019. Multimorbidity, defined as having two or more of 18 chronic conditions (diabetes, high cholesterol/high blood lipids, high blood pressure, ischemic (coronary) heart disease, cerebrovascular disease (stroke)), obesity (BMI above 25 kg/m²), liver disease, kidney disease, goiter/thyroid abnormality, arthritis, depression/anxiety, epilepsy, chronic bronchitis/lung disease, asthma, liver cancer, lung cancer, breast cancer, cancer of the

digestive system), was assessed using baseline TCS data [10]. Independent variables included socio-demographic factors (gender, age, marital status, geographic regions, life course residence, personal monthly income and educational level) and health behaviours/lifestyles (weekly exercise, sedentary time, sleeping time, housework, smoking and drinking) [10].

Survival analysis involved Kaplan-Meier curves illustrating multimorbidity's impact on all-cause deaths from baseline in 2005 to 2019. The log-rank test assessed survival pattern differences based on multimorbidity presence or different numbers of chronic conditions. Univariate and multivariate Cox proportional hazards models examined the association between survival and risk factors, including multimorbidity and the number of chronic conditions. Multivariate models also assessed the interaction between multimorbidity and independent variables. Results were expressed as hazard ratios (HR) with 95% confidence intervals (CI), adjusting for other factors as confounders. Missing data were assumed to be missing at random. P for trend (p-trend) tested linear trends, with statistical significance set at $p < 0.05$. Analyses were conducted using Stata 16.0 [10].

3.5 The methods for Objective 4 – the Narrative review (Chapter 10)

Chapter 10, titled “The Prevention and Management of Multimorbidity in Southeast Asia”, employed a direct narrative synthesis approach [26, 27]. This approach was selected to systematically summarize and integrate findings from existing literature, policies, and intervention reports related to multimorbidity in the Southeast Asian region. By using narrative synthesis, the review enabled the combination of evidence from diverse sources and study designs, including observational studies and policy documents, providing a comprehensive methodological framework for understanding strategies in this area [27].

The review specifically focused on collecting and organizing evidence on the prevention and management of multimorbidity. Data were extracted, categorized, and synthesized narratively to outline current strategies and interventions across Southeast Asia.

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Chapter 4 The systematic review of multimorbidity in Southeast Asia

This paper served as an initial study and laid the foundation for subsequent research on multimorbidity in Thailand. It presented a systematic review of multimorbidity in Southeast Asia, with a particular focus on prevalence and the association between educational attainment, which is an important indicator of socio-economic status, and multimorbidity.

By mapping and synthesizing existing studies, this review contributed to a clearer understanding of multimorbidity prevalence across Southeast Asian countries, including Thailand. It also highlighted the role of educational background as a contributing factor and drew attention to the broader influence of socio-economic status on multimorbidity in the region. Particular attention was given to education and gender due to their strong public health relevance. Education reflects long-term social and economic conditions that shape health behaviors, access to care, and health literacy, while gender differences are consistently observed in health outcomes and service utilization. These dimensions are therefore essential for understanding the patterns and drivers of multimorbidity in Southeast Asia.

In doing so, the review provided important insights, identified knowledge gaps, and suggested directions for future research, especially the need for in-depth country-specific analyses. Building on these findings, the next chapter turns to Thailand, where nationally representative cohort data allow a more detailed examination of multimorbidity. Thailand was selected not only because of the availability of comprehensive longitudinal data from the Thai Cohort Study but also because it is a large middle-income country experiencing rapid demographic and epidemiological transitions, which makes it broadly representative of Southeast Asian contexts.

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

Title: The association between educational level and multimorbidity among adults in Southeast Asia: A systematic review

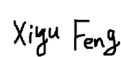
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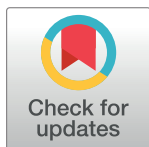
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RESEARCH ARTICLE

The association between educational level and multimorbidity among adults in Southeast Asia: A systematic review

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Abstract

Background

In Southeast Asia, the prevalence of multimorbidity is gradually increasing. This paper aimed to investigate the association between educational level and multimorbidity among over 15-years old adults in Southeast Asia.

Methods

We conducted a systematic review of published observational studies. Studies were selected according to eligibility criteria of addressing definition and prevalence of multimorbidity and associations between level of education and multimorbidity in Southeast Asia. The Newcastle-Ottawa Scale (NOS) was used to measure the quality and risk of bias. The methodology has been published in PROSPERO with registered number ID: CRD42021259311.

Results

Eighteen studies were included in the data synthesis. The results are presented using narrative synthesis due to the heterogeneity of differences in exposures, outcomes, and methodology. The prevalence of multimorbidity ranged from 1.7% to 72.6% among over 18 years-old adults and from 1.5% to 51.5% among older people (≥ 60 years). There were three association patterns linking between multimorbidity and education in these studies: (1) higher education reducing odds of multimorbidity, (2) higher education increasing odds of multimorbidity and (3) education having no association with multimorbidity. The association between educational attainment and multimorbidity also varies widely across countries. In Singapore, three cross-sectional studies showed that education had no association with multimorbidity among adults. However, in Indonesia, four cross-sectional studies found higher educated persons to have higher odds of multimorbidity among over 40-years-old persons.

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Abbreviations: NOS, Newcastle-Ottawa Scale; LMICs, Low- and middle-income countries; SES, Socioeconomic status; PRISMA, Preferred Reporting Items for Systematic reviews and Meta-Analyses; ASEAN, the Association of Southeast Asian Nations; CI, Cumulative incidence; IR, Incidence Rate; CI, Confidence interval; aOR, Adjusted odd ratio; SMHS, Singapore Mental Health Study; TB, Tuberculosis; WiSE, Well-being of the Singapore Elderly; IFLS, Indonesian Family Life Survey.

Conclusions

Published studies have shown inconsistent associations between education and multimorbidity because of different national contexts and the lack of relevant research in the region concerned. Enhancing objective data collection such as physical examinations would be necessary for studies of the connection between multimorbidity and education. It can be hypothesised that more empirical research would reveal that a sound educational system can help people prevent multimorbidity.

Introduction

Multimorbidity, also known as multiple chronic conditions, is generally defined as the presence of two or more chronic health conditions in a person at the same time [1]. Multimorbidity is more common in older adults (more than 60 years old), such as suffering from hypertension, diabetes and chronic kidney disease concurrently [2,3]. Due to global aging, multimorbidity is also becoming a global public health issue [2]. The magnitude of multimorbidity in low- and middle-income countries (LMICs) was estimated at 10% to 11% recently, and it is predicted to increase in the coming years [4]. Due to the complexity of symptoms and higher mortality rates, the treatment requirements for multimorbidity are more complicated than those for single diseases, and patients with multimorbidity often do not receive cost-effective treatment [5]. This situation may increase the economic and medical burden of these patients and lead to a reduced quality of life and greater damage to their physical and mental health [5,6].

In Southeast Asia, the prevalence of multimorbidity is also gradually increasing, from a prevalence of about 4.5% at the beginning of the 21st century to about 10% in recent years [4,7]. There are many factors contributing to the rising prevalence of multimorbidity in Southeast Asia, among which is the rapid socio-economic development of region and the concurrent growth in socioeconomic inequality [8–10]. Socio-economic development is connected to epidemiological transition and the growth of the prevalence of chronic diseases [9]. Moreover, inequalities in socioeconomic status (SES) may be reflected in unequal access to health care, participation in health activities, and life stressors, which would contribute to an increased burden of multiple chronic conditions [9,10]. Furthermore, lower socioeconomic groups who suffer from multimorbidity will suffer more because they have limited access to diagnosis and the burden of expensive treatment [8–10].

Education level generally refers to the highest attained level of education by individuals and is often classified into these levels: no education; elementary school; middle school, junior high school, senior high school, university or higher [9,10]. Moreover, education level, which is a key indicator of SES, may have a greater impact on the prevalence of chronic diseases compared with the other two factors (income and occupation) of SES. This is because in health studies on multimorbidity, measures of SES include income, occupation, and education, but education usually logically determines subsequent occupational and income development [9,10]. Moreover, education may also influence health literacy, leading to a potential role in reducing the prevalence of multimorbidity. Furthermore, educational inequalities are evident in Southeast Asian and are possibly influencing patterns of multimorbidity. In Southeast Asian nations, disparity in access to educational resources is common, often also along gender lines [11–13]. Thus, in this article, education level will be used as an exposure factor to measure its effect on multimorbidity in Southeast Asia.

Studies to date in Southeast Asia which have assessed associations between the education level and multimorbidity have had mixed outcomes. For example, some studies have concluded that lower education levels cause an increase in the prevalence of multimorbidity [14,15]. But other studies have established that the level of education was not connected with the prevalence of multimorbidity [16]. It is hypothesized that in high-income countries, education may prevent the occurrence of multimorbidity, but in LMICs, education may be a risk factor for multimorbidity [8,9]. Nevertheless, to date, no article has conducted a comprehensive systematic review of the association between multimorbidity and education level among populations living in Southeast Asia.

Therefore, this paper is the first attempt to provide an overview of studies on multimorbidity and educational attainment in Southeast Asia and to systematically evaluate published observational studies. The aim of this paper was to better understand the association between educational attainment and multimorbidity in Southeast Asia, which may help to identify potential causes of multimorbidity in these places and to design appropriate interventions to prevent or reduce the occurrence of multimorbidity.

Methods

A systematic review of published articles reporting multimorbidity and educational level among adults in Southeast Asia was conducted using the terms of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement (S3 Table) [17]. The methodology has been published in PROSPERO with registered number ID: CRD42021259311 (S1 File).

Inclusion and exclusion criteria

Articles were selected based on the following inclusion criteria, (1) quantitatively designed observational studies; (2) studies reporting multimorbidity being defined as a person having two or more chronic conditions at the same time; (3) studies reporting or having available detailed data on associations between level of education and multimorbidity; (4) studies in which the study sites including either individual Southeast Asian countries or the Southeast Asian region, with the definition according to countries belonging to the Association of Southeast Asian Nations (ASEAN), which included Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam; (5) the associations between education level and multimorbidity in the Southeast Asian region or Southeast Asian countries being reported in studies examining the regional level, such as at the level of LMICs or at the global level; (6) participants in studies being over 15 years of age; and (7) English-language studies being published between 1990 and 2021 due to the term of “multimorbidity” first being coined in the early 1990s [18].

The exclusion criteria were [18,19]: (1) book series and conferences; (2) qualitative studies; (3) non-observational studies; (4) studies reporting co-morbidity (studies with an index disease), such as multimorbidity among patients with diabetes, HIV or hypertension; (5) studies where detailed data was not available regarding the association between educational level and multimorbidity; (6) study sites not in Southeast Asian region or in Southeast Asian countries; (7) studies of examining the regional level such as LMICs level and global level not reporting the associations between education level and multimorbidity in Southeast Asia region or Southeast Asian countries; (8) participants in studies was younger than 15 years; and (9) studies not published in English, and not published between 1990 and 2021.

Search strategy and the selection of literature

The databases of Scopus, PubMed and ProQuest were used to search for relevant articles. We classified the search terms according to exposure, outcomes and location (S1 Table) [18,19]: (1) Exposure: 'education, literacy, educational status, educational level, educational attainment'. (2) Outcome: 'multimorbidity, multimorbidity, multimorbid, multiple morbidities, multiple morbidity, multiple conditions, multiple diseases, multiple chronic diseases, multiple chronic conditions, multiple illnesses, multiple diagnoses, multi-pathology'. (3) Location: 'Southeast Asia, Association of Southeast Asian Nation, ASEAN, Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam'. The 'AND' was used to the combination of search terms across the categories and 'OR' was combined within the categories. In addition, a term similar to the definition of multimorbidity is comorbidity, but in 2018, a distinction has been made between the definition of comorbidity and multimorbidity, and while both terms emphasize the co-existence of multiple chronic conditions in the same individual, the term of "comorbidity" means the combined effects of additional conditions with reference to the index chronic condition such as the comorbidity of diabetes, stroke, or depression [1]. Namely, comorbidity is the presence of one or more additional diseases, as a result of the presence of the index condition [19]. Although, these two terms have different definition, multimorbidity and comorbidity are commonly used interchangeably [1,8]. Thus, after the initial search, the addition of 'comorbidity' was added into our search to test if any articles had been missed through the exclusion of the term of 'comorbidity' and linguistic changes of the term of 'comorbidity' [18].

Furthermore, the studies in this paper only involved human participants, were published from 1990/01/01 to 2021/06/15, and had abstracts available. We used the hand search in the references of retrieved studies to identify additional relevant papers.

The first reviewer (XF) performed an initial screening of titles and abstracts for all keywords searched. The second reviewer (MK) conducted a 20% random sample of all references to ensure that eligible studies were not omitted [18]. Studies that met all of the above eligibility criteria were retained for full-text screening. Full-text screening was done independently by two reviewers (XF and MK). When disagreements arose, XF and MK resolved them through discussion. When agreement could not be reached, a third reviewer (HS) was consulted. Disagreements were eventually resolved by consensus.

The assessment of quality

Two authors (XF and MK) independently assessed the risk of bias and study quality in cohort studies and case-control studies using the Newcastle Ottawa Scale (NOS), one of the risk of bias assessment tools recommended by the Cochrane Collaboration for use in observational studies [20], and cross-sectional studies using adaptations of the NOS (S2 File and S2 Table) [19,21]. For observational studies, the checklist focused on three aspects (Selection, Comparability and Exposure/Outcome).

The examined selection of observational studies according to NOS was shown in the table below (Table 1) [19,21]. Observational studies included cross-sectional studies, cohort studies and case-control studies. The selection table was based on a summary of the scored items for each of the observational studies in NOS (S2 File), with reference to other systematic reviews of multimorbidity that have applied NOS as an assessment tool to evaluate and examine the literature [19,21].

There were three levels of quality to assess the scores of the individual study in the table below (Table 2) [19,21]. The scores of NOS corresponding to the three levels mentioned in the

Table 1. The examined selection of observational studies according to NOS.

	Cross-sectional studies (Seven items, maximum ten points)	Cohort studies (Eight items, maximum nine points)	Case-control studies (Eight items, maximum nine points)
Selection	(Up to five points)	(Up to four points)	(Up to four points)
	Representativeness;	Representativeness;	Adequate definition;
	Sample size;	Non exposed cohort;	Representativeness;
	Non-respondents;	Ascertainment;	Selection of controls;
Comparability	Ascertainment.	Demonstration.	Definition of controls.
	(Up to two points)	(Up to two points)	(Up to two points)
	On the basis of the study design or analysis and the control of confounders.	On the basis of the design or analysis.	On the basis of the design or analysis.
Outcome/ Exposure	(Up to three points)	(Up to three points)	(Up to three points)
	Assessment;	Assessment;	Ascertainment;
	Statistical test.	Enough long follow-up;	Same method of ascertainment;
		Adequacy.	Non-response rate.

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table were summarized from similar levels and scores that appeared in other systematic reviews of multimorbidity [19,21].

Two reviewers (XF and MK) independently decided on the summary measurement of the relevant articles. The risk of bias was assessed as the sum of the scores for each item. Each reviewer independently determined an overall quality score for each article. It should be noticed that if one of the three aspects (Selection, Comparability and Exposure/Outcome) was given a zero score, the level was Poor, regardless of the total scores of all three aspects. The final article selection was based on the scores of the three aspects (Selection, Comparability and Exposure/Outcome). To be retained in our systematic review, articles should have had a quality score of four scores or above (S2 Table) [19,21].

Data extraction

For each included study, we extracted the following information [18,19]: (1) the author(s) and publication year; (2) study country/location; (3) study design and study population (4) sample size: total number; (5) sample characteristics: the percentage of male (%); (6) sample characteristics: mean age and/or the range of age (years); (7) data collection; (8) the definition of multi-morbidity and the number of conditions or diseases; (9) the subdivision of educational attainment; (10) the prevalence/incidence of multimorbidity (11) the prevalence/incidence of multimorbidity in terms of educational level; and (12) the main results of the association between multimorbidity and education (including analytical adjustments made).

Data synthesis

Because of the different exposures, outcomes, and study methods, the included studies were judged to be heterogeneous in distinct ways such as populations, the definition of variables

Table 2. Three levels of quality to assess the scores of the selected studies.

	Selection	Comparability	Outcome/Exposure	Total
Good	Four points or above	One point or above	Two points or above	Seven points and above
Fair	Two to three points	One point	One to two points	Five to six points
Poor	Zero to one point	Zero point	Zero point	Zero to four points

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and different confounders. Taking this heterogeneity into account, we were unable to perform a meta-analysis of the findings [18,22].

The findings regarding methods, exposures, and outcomes were described using narrative synthesis [18,22]. The prevalence of multimorbidity was extracted from individual studies. The extraction of the prevalence of multimorbidity was divided into three cases in these studies. (1) The prevalence of multimorbidity was reported directly in the study, thus we could extract data on the prevalence of multimorbidity directly from the article. (2) If the prevalence of multimorbidity was not directly reported in the study but it reported the total number of participants and the number of people with multimorbidity, we calculated this indicator using the number of participants as the denominator and the number of people with multimorbidity as the numerator. (3) If studies did not report the prevalence of multimorbidity, the total number of participants and the number of multimorbidity cases, we categorised those studies “not available” (N/A).

The available data regarding education level in the survey area were pooled in the same way to extract and calculate the prevalence (%) of multimorbidity at different education attainments. The prevalence of multimorbidity (%) at different education levels in the study was all obtained by calculation in selected studies. The prevalence of multimorbidity for a particular education level group was calculated by dividing the number of participants experiencing multimorbidity at that educational attainment level by the total sample number of participants. For studies that we could not calculate the prevalence of multimorbidity (%) at different educational levels because of lack of reporting the number of patients with multimorbidity (numerator) at different educational levels, we would put “N/A” to show the prevalence.

All studies reported the ratios of multimorbidity at different educational levels. Therefore, the ratios in this paper were used directly from the ratios given in each study.

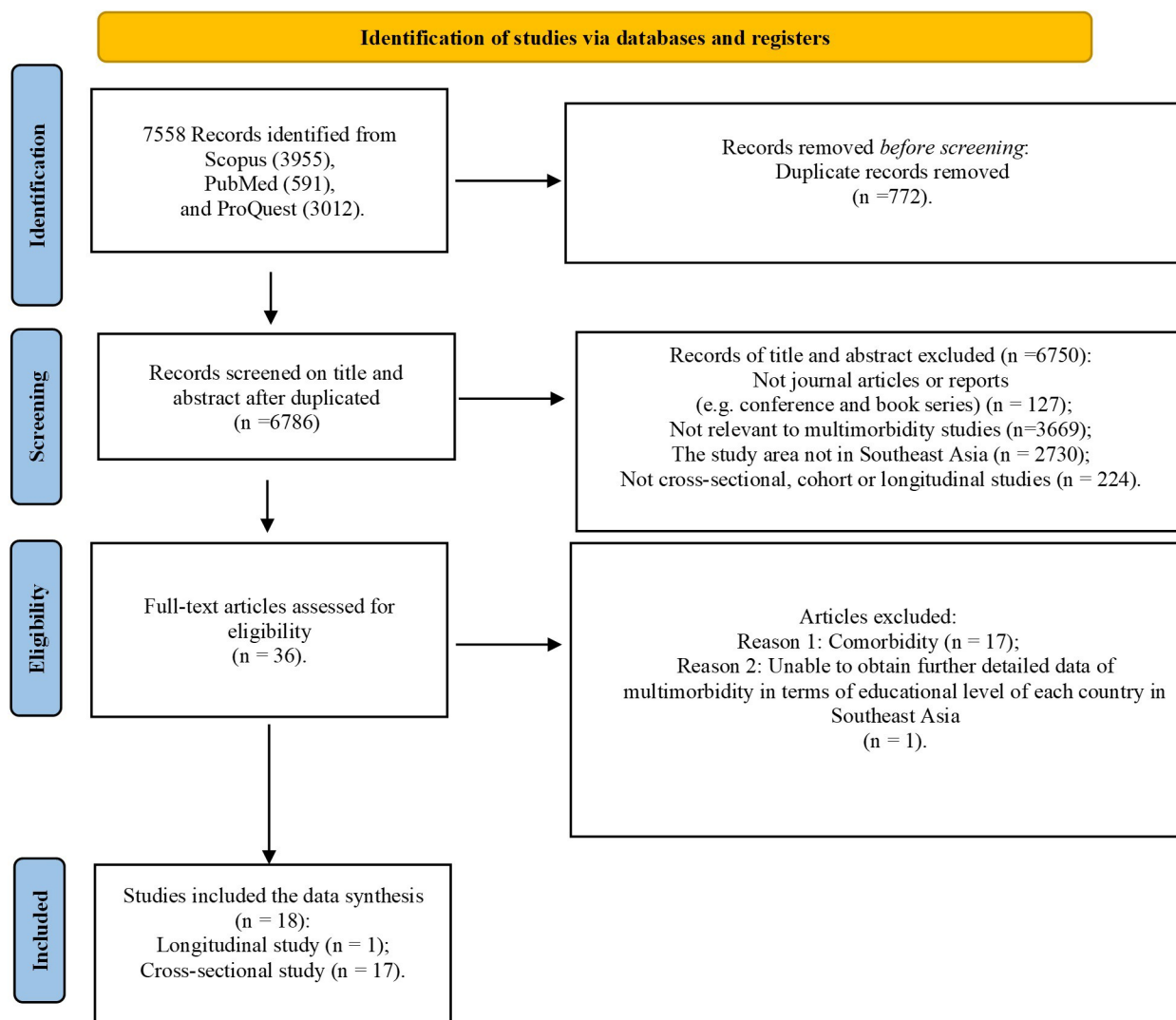
Results

Yield of search strategy

The electronic and manual searches yielded 7,558 articles. After eliminating duplicate articles, 6,786 articles were selected for the title and abstract screening. After carefully screening the titles and abstracts, 36 articles were found to be available for full-text review. A further 18 articles were then removed due to their addressing comorbidity (17 articles) and being unable to obtain detailed data of multimorbidity in terms of educational level in Southeast Asia (1 article). Finally, 18 articles were included in this systematic review (Fig 1) [14–16,23–37]. Seventeen papers were cross-sectional studies [14–16,23–28,30–37], and one paper was a longitudinal study [29]. No studies were case-control studies.

Study selection and characteristics

Table 3 detailed the key characteristics of the included studies. Two multi-country studies implemented in different Southeast Asian countries were included in this review [14,16]. Five studies were from Singapore [23,27,34–36], four studies were from Indonesia [24,28,30,31], three studies were from Vietnam (all from different parts of Vietnam) [15,26,32], two studies were from Thailand [33,37], one was from Myanmar [25] and one was from Malaysia [29]. Sample sizes of selected studies ranged from 729 [24] to 13,798 [29]. Just one article did not calculate the prevalence or incidence of multimorbidity [30]. The only longitudinal study showed the incidence of half year cumulative incidence and the incidence rate (IR) for multimorbidity [29]. Nine cross-sectional articles directly showed the number of participants



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For more information, visit: <http://www.prisma-statement.org/>

Fig 1. PRISMA flow diagram. Description of article selection process.

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experiencing multimorbidity at that educational attainment level and the total sample number to get the prevalence of multimorbidity at different educational levels [15,23–26,31–34]. Six studies included only participants aged 60 years and older [15,25,29,32,34,36].

On the NOS, six studies were scored Good level of quality [15,24,28,30,31,36] nine studies (including the only longitudinal study [29]) were at Fair level [14,16,23,25,26,29,33,34,37], and three studies were at Poor level [27,32,35] (Table 3).

Table 3. The key characteristics of selected studies.

Study	Study area	Method				Results		Other				
First author (year)	Country/ Location	Study population and study design	Sample size (N)	Men (%)	Mean or Medium age (years) (range)	Data collection	Definition of multimorbidity	Number of conditions	Educational level	Prevalence/Incidence of multimorbidity (95% CI) ^a	Prevalence/Incidence of multimorbidity in terms of educational level (%) ^b	Scores in NOS (Level)
Cross-sectional studies												
Abidin (2020) [23]	Singapore	Singapore Mental Health Study (SMHS)-2010 and SMHS-2016;	SMHS-2010 = 6616 citizens; SMSH-2016 = 6126 citizens	SMHS-2010 = 48.5%; SMSH-2016 = 49.6%	Mean: N.A. ≥18 years	Fully structured diagnostic interview (mental disorders); Self-reported (physical disorders)	"Co-morbidity of mental and physical disorders."	3 Mental disorders: "major depressive disorder, dysthymia and bipolar disorder; anxiety disorders, including generalised anxiety disorder and obsessive-compulsive disorder; and alcohol abuse and dependence"; 10 Physical disorders: "asthma, diabetes mellitus, hypertension and high blood pressure, chronic pain, cancer, cardiovascular disorders, ulcer and chronic inflamed bowel, thyroid disease, neurological condition, chronic lung disease."	Primary and below; Secondary; Diploma; Vocational; University	SMHS-2010 = 5.8% (5.3–6.4%); SMHS-2016 = 6.7% (6.1–7.3%)	SMHS-2010: Primary and below = 0.67% (0.48–0.90%); Secondary = 1.6% (1.3–1.9%); Diploma = 1.4% (1.4–2.1%); Vocational = 0.51% (0.36–0.71%); University = 1.2% (0.95–1.5%) (1.2–1.9%)	6 (Fair)
Alshar (2015) [16]	Laos; Malaysia; Myanmar; Philippines	WHO World Health Survey (WHS)	Laos = 4989; Malaysia = 6145; Myanmar = 6045; Philippines = 10083	Laos = 49.3%; Malaysia = 50.4%; Myanmar = 48.9%; Philippines = 49.6%	Mean: N.A. (≥18 years)	Self-reported	"The presence of two or more chronic diseases."	6 conditions: "arthritis, angina or angina pectoris (a heart disease), asthma, depression, schizophrenia or psychosis, and diabetes."	< Primary; Primary school; Secondary Higher	(Standardised prevalence) Laos = 3.6% (3.1–4.1%); Malaysia = 5.6% (5.0–6.2%); Myanmar = 1.7% (1.4–2.0%); Philippines = 7.1% (6.6–7.7%);	N/A	6 (Fair)
Anindya (2021) [24]	Indonesia	2014/2015 Indonesian Family Life Survey (IFLS-5)	13,798 adults	49%	Mean: 58 years, Interquartile range (IQR): 54–65 years (≥40 years)	Self-reported; Medical examination	"The presence of two or more Chronic non-communicable diseases (NCDs)."	14 NCDs: "high blood pressure, diabetes, asthma, heart attack/coronary heart disease, liver disease, stroke, cancer, arthritis/rheumatism, high cholesterol, prostate illness, kidney disease (excluding malignancy), digestive disease, mental illness, memory related diseases."	No education; Primary; Junior high school; Senior high school; Tertiary	20.84% (20.12–21.57%)	No education = 8.2% (7.8–8.7%); Primary = 5.1% (4.7–5.5%); Junior high school = 2.5% (2.2–2.7%); Senior high school = 4.0% (3.7–4.3%); Tertiary = 2.2% (2.0–2.5%)	8 (Good)
Aye (2019) [25]	Myanmar	Community-based cross-sectional study	4,859 participants	37.9%	Mean: N.A. (60–106 years, 46.0% participants ≥70 years)	Face-to-face interview with a semi-structured paper questionnaire	"Two or more chronic conditions"	14 chronic conditions "high blood pressure, coronary heart disease or heart attack, heart failure, irregular heart-beat, chronic bronchitis or chronic obstructive airway disease, asthma, stroke, diabetes, arthritis or rheumatoid arthritis, osteoporosis, glaucoma, cataract, depression, and emotional or mental illness."	Diploma/ Graduate; Middle to High school; Below Middle school; Illiterate	33.2% (31.9–34.5%)	Illiterate = 3.3% (2.8–3.8%); Below Middle school = 19.9% (18.5–20.8%); Middle to High school = 8.2% (7.4–8.9%); Diploma/graduate = 1.8% (1.4–2.1%);	6 (Fair)
Ba (2019) [26]	Central Highlands Region (Tay Nguyen) of Vietnam	Cross-sectional study	1,680 people	50.1%	Medium: 38.0 years, IQR: 30.5–43.0 years (≥15 years)	Self-reported	"The presence of two or more chronic conditions."	At least 8 chronic conditions: "cancer, heart and circulatory conditions, chronic joint problems, chronic pulmonary diseases, chronic kidney problems, chronic digestive problems, psychological illness, diabetes, and/or other chronic conditions."	Secondary or less; High school; University	16.4% (14.6–18.2%)	Secondary or less = 9.5% (8.1–11.0%); High school = 2.4% (1.7–3.2%); University = 4.5% (3.6–5.6%)	6 (Fair)
Chong (2012) [27]	Singapore	Singapore Mental Health Study (SMHS)-2010	6,616 participants	48.5%	43.9 years (standard error (SE): ± 0.3 years) (≥18 years)	Face-to-face fully structured diagnostic interview (mental disorders); Self-reported (physical disorders)	"Co-morbidity of mental and physical disorders"	5 Mental disorders: "major depressive disorder, bipolar disorder, generalised anxiety disorder, obsessive compulsive disorder, alcohol abuse and alcohol dependence"; 8 Physical disorders: "respiratory disorders (asthma, chronic lung disease), diabetes, hypertension and high blood pressure, chronic pain (arthritis or rheumatism, back problems including disk or spine, migraine headaches), cancer, neurological disorders (epilepsy, convulsion, Parkinson's disease), cardiovascular disorders (stroke or major paralysis, heart attack, coronary heart disease, angina, congestive heart failure or other heart disease), ulcer and chronic inflamed bowel (stomach and chronic inflamed bowel, enteritis, or colitis)."	Pre-primary; Primary; Secondary; Pre-U/Junior College/ Diploma; Vocational; University	6.1% (5.5–6.7%)	N/A	6 (Poor)

(Continued)

Table 3. (Continued)

Study	Study area	Study population and study design	Sample size (N)	Men (%)	Mean or Median age (years) (range)	Data collection	Definition of multimorbidity	Number of conditions	Educational level	Prevalence/Incidence of multimorbidity (95% CI) ^a	Results	Other
Ha (2015) [13]	Southern Vietnam	Community-based cross-sectional study	2400 people	34.8%	Mean: 72.6 years, standard deviation (SD): 48.3 years (≥60 years)	Medical examination and chart review	"Having at least two of the conditions"	6 broad groups of conditions: "cardiovascular (including hypertension, digestive system (including liver), respiratory (including chronic obstructive pulmonary disease and tuberculosis), arthritis (including osteoarthritis), genitourinary, and diabetes."	Illiterate; Literacy	39.2% (39.5–43.8%) Illiterate = 10.05% (8.9–11.3%); Literate = 31.4% (29.6–33.3%)		7 (Good)
Hussain (2015) [28]	Indonesia	Indonesian Family Life Survey (IFLS-4)	9438 Indonesia adults	46.6%	Male median: 52 years, IQR: 45–61 years (≥40 years); Female median: 52 years, IQR: 45–62 years (≥40 years)	Active measurement or through self-report or both	"The presence of two or more chronic conditions in individual respondent"	12 chronic conditions: "hypertension, diabetes, tuberculosis, asthma and other chronic lung diseases, cardiac diseases, liver diseases, stroke, cancer or malignancies, arthritis/rheumatism, uric acid/gout, depression, vision and hearing abnormalities."	Elementary or less; High school; Graduate and above	N/A		7 (Good)
Liew (2011) [30]	Indonesia	2007 Indonesian Family Life Survey (IFLS4)	3061 individuals	51.2%	Male mean age: 54.01 years (40–93 years) Female mean age: 53.88 years (40–94 years)	Interview	"At least two chronic health conditions"	10 chronic conditions: "hypertension, diabetes, tuberculosis, asthma, heart attack, liver disease, stroke, cancer, arthritis, gout."	Up to primary; Secondary; College and university	N/A		8 (Good)
Marthias (2021) [31]	Indonesia	Indonesian Family Life Survey (IFLS) conducted in Wave 4 2007 and Wave 5 2014	Wave 4 (2007): 3678 respondents Wave 5 (2014): 3678 respondents	46.1%	Wave 4 (2007): Medium age: 58 years, IQR: 54–65 years (≥50 years); Wave 5 (2014): Medium age: 65 years, IQR: 60–72 years (≥50 years)	Self-reported and physical examination	"Two or more non-communicable diseases (NCDs)"	10+4 NCDs: "Wave 4: hypertension, diabetes, asthma, heart attack/coronary heart diseases, liver disease, stroke, cancer, arthritis/rheumatism, high cholesterol, depression/mental illness (Wave 5 added: prostate diseases, kidney diseases (excluding malignancy), digestive diseases, memory-related diseases)."	No education; Primary; Junior high school; Senior high school; Tertiary	Wave 4 (2007) = No education = 11.6% (10.4–12.4%); Primary = 4.8% (4.2–5.6%); Junior high school = 1.9% (1.5–2.4%); Senior high school = 1.8% (1.4–2.3%); Tertiary = 1.2% (0.87–1.6%) Wave 5 (2014) = No education = 10.3% (9.3–11.3%); Primary = 5.6% (4.9–6.4%); Junior high school = 2.7% (2.2–3.2%); Senior high school = 2.5% (2.0–3.0%); Tertiary = 1.6% (1.2–2.0%)		7 (Good)
Mwangi (2019) [32]	rural Northern Vietnam (Flabavi)	Flabavi Demographic Surveillance site in rural Vietnam	2873 people	41.6%	Mean: N.A. (≥60 years)	Self-reported	"Multiple diseases"	8 non-communicable diseases (NCDs): "hypertension, diabetes, cancer, arthritis/osteoarthritis, stroke, angina-pectoris, chronic bronchitis, cataract."	Illiterate; Read and write only; Primary; Secondary; Above high school	(Aggregated self-reported) 2 common chronic diseases (CCDs) = 9.2% (8.2–10.3%); ≥3 CCDs = 3.5% (2.8–4.1%)	≥2 CCDs: Illiterate = 2.0% (1.5–2.6%); Read and write only = 4.9% (4.2–5.8%); Primary/secondary = 4.4% (3.7–5.2%); High school = 0.6% (0.35–0.95%); Above high school = 0.8% (0.51–1.2%)	4 (Poor)
Pengpid (2017) [14]	Four Greater Mekong countries: Cambodia, Myanmar, Thailand, Vietnam	A cross-sectional survey	6236 participants	33.8%	Mean: 53.0 years, SD: ±16.8 years (18–94 years, 59.8% participants ≥50 years)	Interviewed with a structured questionnaire	"Two or more chronic conditions"	21 chronic conditions: "asthma, chronic obstructive pulmonary disease, diabetes mellitus, hypertension, dyslipidaemia, coronary artery disease, cardiac failure, cardiac arrhythmias, stroke, arthritis, cancer, gout, Parkinson's disease, liver disease, kidney disease, thyroid disease, stomach and intestinal diseases, epilepsy, mental disorders."	Grade 0–5; Grade 6–11; Grade 12 or more	All: 72.6% (71.5–73.7%) two conditions: 28.6% (27.5–29.8%); three conditions: 22.4% (21.4–23.5%); and four or more conditions: 21.6% (20.6–22.6%)	N/A	6 (Fair)

(Continued)

Table 3. (Continued)

Study	Study area	Method						Results		Other		
First author (year)	Country/ Location	Study population and study design	Sample size (N)	Men (%)	Mean or Medium age (years) (range)	Data collection	Definition of multimorbidity	Number of conditions	Educational level	Prevalence/incidence of multimorbidity (95% CI) ^a	Prevalence/incidence of multimorbidity in terms of educational level (%) ^b	Scores in NOS (Level)
Pengpid (2021) [33]	Thailand	A cross-sectional survey	1409 attendees	24.5%	Mean age in monk healer setting: 47.3 years Mean age in health centre: 53.3 years (≥19 years)	Self-reported	"Two or more chronic conditions"	16 chronic conditions: "hypertension, heart attack or stroke, high blood cholesterol, diabetes, emphysema/asthma, sore joints, osteoporosis, cancer or malignancy, migraine headaches, ulcer, fatigue disorder, sleeping problem, common mental disorder: somatization, generalized anxiety disorder and major depression, substance use disorder."	Primary or less: Secondary; Post-secondary	All: 45.2% (42.6–47.9%) Monk healer: 23.0% (20.9–25.4%); Health centre: 22.1% (20.0–24.4%)	All: Primary or less = 26.2% (23.9–28.6%); Secondary = 9.9% (8.4–11.6%); Post-secondary = 9.1% (7.6–10.7%); Monk healer: Primary or less = 8.9% (7.5–10.6%); Secondary = 6.7% (5.5–8.2%); Post-secondary = 7.4% (6.1–8.9%) Health centre: Primary or less = 17.3% (15.3–19.3%); Secondary = 3.2% (2.3–4.3%); Post-secondary = 1.7% (1.1–2.5%)	5 (Fair)
Picco (2016) [34]	Singapore	The Well-being of the Singapore Elderly (WISE) a population-based, cross sectional study	2565 citizen and permanent residents	44.1%	Mean: N.A. (75% participants 60–74 years)	Self-reported	"Two or more of these chronic conditions being present in the one person at the same time"	10 chronic conditions: "high blood pressure, heart trouble, stroke, transient ischemic attacks, diabetes, depression, arthritis or rheumatism, chronic obstructive pulmonary diseases, breathlessness or asthma, cancer."	No education; Some, but did not complete primary; Completed primary; Completed secondary; Completed tertiary	51.5% (50.0–53.5%)	None = 12.4% (11.1–13.7%); Did not complete primary = 13.5% (12.2–13.7%); Primary = 13.3% (12.2–14.8%); Secondary = 8.3% (7.2–9.4%); Tertiary = 4.3% (3.5–5.1%)	6 (Fair)
Subramaniam (2014) [35]	Singapore	Singapore Mental Health Study (SMHS) a population-based, cross sectional study	6616 participants	49.9% (unweighted) 48.5% (weighted)	Mean: N.A. (≥18 years)	Self-reported	"Multiple chronic medical conditions (MCMC)"	15 chronic conditions in 8 types: "respiratory disorders (asthma, chronic lung disease), diabetes, hypertension and high blood pressure, chronic pain (arthritis or rheumatism, back problems including disk or spine, migraine headaches), cancer, neurological disorders (epilepsy, convulsion, Parkinson's disease), cardiovascular disorders (stroke or major paralysis, heart attack, coronary heart disease, angina, congestive heart failure or other heart disease), ulcer and chronic inflamed bowel (stomach ulcer, chronic inflamed bowel, enteritis, or colitis)."	Primary and below: Secondary; Pre-U/Junior College/ Diploma; Vocational; University	15.0% (unweighted) 16.3% (weighted) (14.2–15.9%)	Primary and below = 5.4% (4.8–5.9%); Secondary = 6.7% (6.1–7.3%); Pre-U/Junior College/Diploma = 2.1% (1.7–2.4%); Vocational = 1.0% (0.73–1.2%); University = 2.0% (1.6–2.3%)	5 (Poor)
Subramaniam (2017) [36]	Singapore	the Well-being of the Singapore Elderly (WISE) a population-based, cross sectional study	2565 respondents	43.5% (unweighted) 44.0% (weighted)	Mean: N.A. (≥60 years)	Professional examination; self-reported	Comorbid Diabetes and Depression	2 conditions: "diabetes and depression."	None; Some, but did not complete primary; Completed primary; Completed secondary; Completed tertiary	2.8% (unweighted) 1.5% (weighted) (2.2–3.5%)	N/A	8 (Good)
Tiptaradol (2012) [37]	Thailand	Thai National Health Examination Survey III	36,877 participants	47.8%	Mean: N.A. (≥15 years)	Health examination	Coexistence of Diabetes and Hypertension.	2 conditions: "diabetes and hypertension."	No formal education; Less than 6 years; Secondary; University	All: 3.2% (2.9–3.6%),	N/A	6 (Fair)

Longitudinal studies

(Continued)

Table 3. (Continued)

Study	Study area	Method					Results		Other			
First author (year)	Country/ Location	Study population and study design	Sample size (N)	Men (%)	Mean or Medium age (years) (range)	Data collection	Definition of multimorbidity	Number of conditions	Educational level	Prevalence/Incidence of multimorbidity (95% CI)	Prevalence/Incidence of multimorbidity in terms of educational level (%) (Level)	Scores in NOS (Level)
Hussin (2019) [29]	Malaysia	Community-based longitudinal study; Follow up 0.5 year	729 participants (349 without any chronic disease and 380 with one disease at baseline)	No disease = 51.3%; One disease = 49.2%	Mean: No disease at baseline = 68.3 years, SD: 16.0 years (≥ 60 years); Mean: One disease at baseline = 69.4 years, SD: 16.4 years (≥ 60 years)	Self-reported	"Co-occurrence of two or more diseases within a single individual"	15 diseases: "hypertension, high cholesterol, diabetes, stroke, osteoarthritis, heart diseases, cataract/ glaucoma, renal failure, asthma, chronic obstructive pulmonary disease, tuberculosis, gout, hip fracture, thyroid disorders, cancer."	No schooling; 1–6 years; 7–11 years; 12 years and more	No disease at baseline half-of-year cumulative incidence for multimorbidity: 18.8% (incidence rates were 13.7 per 100 person-years); One disease at baseline Half-of-year cumulative incidence for multimorbidity: 40.9% (incidence rates were 34.2 per 100 person-years)	N/A	5 (Fair)

N/A: Not available.

^{*} If the type of studies could not extract or calculate the prevalence of multimorbidity, the cumulative incidence (CI, %) of multimorbidity could be extracted directly from the study or calculated. The formula was calculated by dividing the number of new multimorbidity cases in a given period by the number of subjects at risk in the population initially at risk of multimorbidity at the start of the study. If the CI for multimorbidity could neither be extracted nor calculated from the study, it should be denoted by N/A.

[#] If the type of studies could not extract or calculate the prevalence (%) of multimorbidity at different educational levels, it was treated in same way as if the type of studies could not extract or calculate the prevalence of multimorbidity.

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Definition and measure of multimorbidity

Twelve studies defined multimorbidity as two or more chronic conditions [Table 3] [14–16,24–26,28–31,33,34]. Two studies defined only multiple diseases but did not emphasize a specific number of diseases [32,35]. Four studies defined multimorbidity as the coexistence of two chronic conditions [23,27,36,37], but not the combined effects of additional conditions with reference to the index chronic condition, unlike the definition of co-morbidity. The number of chronic conditions measured were from two [23,36,37] to twenty-one [14] in these studies. Multimorbidity in twelve studies included psychological disorders in addition to physical disorders [14,16,23–28,31,33,34,36], and four studies' multimorbidity included tuberculosis (TB) (an infectious disease) [15,28–30].

To determine the outcome of the condition, seven studies used self-report to collect data [16,26,29,32–35] and four studies used a combination of medical or professional examination and self-reports [24,28,31,36]. But one study used only health examination [37].

The prevalence of multimorbidity and multimorbidity in terms of education

The prevalence of multimorbidity ranged from 3.2% to 72.6% among over 15 years-old participants. Moreover, the prevalence ranged from 1.5% to 51.5% among older people (more than 60 years old) (Table 3).

The prevalence of multimorbidity was from 20.84% (≥ 40 years old) [24] to 35.7% (≥ 40 years old) [28] in Indonesia [24,28,30,31], and in all four studies [24,28,30,31] higher education related to higher odds of multimorbidity among over 40-years-old persons. The prevalence was from 1.5% [36] to 51.5% among people over 60 years old [34] and from 5.8% [23] to 45.2% [33] among people (≥ 18 years old) in Singapore, and three [23,35,36] in all five studies [23,27,34–36] showed that education had no association with multimorbidity. The prevalence of multimorbidity was from 12.7% among older people (≥ 60 years old) [32] to 39.2% among over 60-years-old people [15] in different parts of Vietnam [15,26,32], and two studies [15,26] suggested that education may reduce people's odds of developing multimorbidity but the age of the study population (≥ 18 years vs. ≥ 60 years) for these two articles were different (Tables 3 and 4).

Association between educational level and multimorbidity

There were three outcomes of these studies. First, higher education reduced odds of suffering from multimorbidity [14,15,26,27,30,33,34], second was that lower education reduced likelihood of having multimorbidity [24,35,28,30,31,33,37] and third was that educational attainment was not related to multimorbidity [16,23,28,29,32,33,35,36] (Table 4).

Higher education reducing odds of multimorbidity

Seven cross-sectional studies [14,15,26,27,30,33,34] found education has been associated with reducing odds of multimorbidity. The study of Liew [30], found a higher level of education was beneficial for the health of over 40-year-old Indonesian women to fight against multimorbidity (all p -value < 0.05) after controlling for mobility problems, age, marital status, and smoking. Similar results were found in studies in other countries such as Vietnam [15,26]. For example, in accordance with the study of Ba *et al* in Central Highlands Region of Vietnam [26], after controlling for gender, age, education, and occupation, over 15-year-old participants with a high school education had significantly lower odds of suffering from multimorbidity compared to those with secondary or less school education (adjusted odd ratio (aOR) 0.8, 95%

Table 4. The association between educational level and multimorbidity.

First author (year), Study area, Study design, Age range	The association between educational level and multimorbidity (value, (95% CI, <i>p</i> -value))					The main results of the relationship between educational level and multimorbidity	Adjusted factors
Abdin (2020) Singapore. Cross-sectional. ≥18 years [23]	Educational level	SMHS-2010 & SMHS-2016		Year of survey interaction		No association between educational level and multimorbidity. After adjusting for all covariates, the likelihood of having comorbid mental and physical conditions over time was significantly lower in secondary school than those in university (aOR 0.5, 95% CI 0.3–0.9).	Age, sex, ethnicity, marital status, (education), and employment.
	Primary and below	OR 0.9 (0.6–1.5, <i>p</i> = 0.787)		(2016) OR 1.02 (0.5–2.2, <i>p</i> = 0.954)			
	Secondary	OR 1.2 (0.9–1.7, <i>p</i> = 0.266)		(2016) OR 0.5 (0.3–0.9, <i>p</i> = 0.034)			
	Diploma	OR 1.2 (0.9–1.7, <i>p</i> = 0.171)		(2016) OR 0.8 (0.5–1.6, <i>p</i> = 0.650)			
	Vocational	OR 1.3 (0.9–2.0, <i>p</i> = 0.178)		(2016) OR 1.2 (0.5–2.7, <i>p</i> = 0.631)			
	University (Reference)	OR 1.0		(2010) OR 1.0			
Afshar (2015) Laos, Malaysia, Myanmar, Philippines. Cross-sectional. ≥18years [16]	Educational level	Laos	Malaysia	Myanmar	Philippines	No association between educational level and multimorbidity. Educational levels were not associated with multimorbidity in these four countries after controlling the adjustment. (all <i>p</i> -value>0.05)	Age and gender.
	< Primary	OR 1.3 (<i>p</i> >0.05)	OR 1.1 (<i>p</i> >0.05)	OR 0.6 (<i>p</i> >0.05)	OR 1.6 (<i>p</i> >0.05)		
	Primary school (Reference)	OR 1.0	OR 1.0	OR 1.0	OR 1.0		
	Secondary	OR 0.5 (<i>p</i> >0.05)	OR 0.8 (<i>p</i> >0.05)	OR 1.5 (<i>p</i> >0.05)	OR 1.1 (<i>p</i> >0.05)		
	Higher	OR 0.3 (<i>p</i> >0.05)	OR 0.8 (<i>p</i> >0.05)	OR 1.2 (<i>p</i> >0.05)	OR 0.7 (<i>p</i> >0.05)		
Anindya (2021) Indonesia. Cross-sectional. ≥40 years [24]	Educational level					Higher educational level increasing odds of multimorbidity. The prevalence of multimorbidity was greater in higher educated people. Participants with tertiary or higher education had more 1.60 times of odds (95% CI 1.32–1.93) to have multimorbidity compared with those who did not receive education after controlling for the confounders.	Age, gender, marital status, (education), residency, region, per capita expenditure (PCE) quartile and have or not health insurance.
	No education (Reference)	OR 1.00					
	Primary	OR 1.22 (1.08–1.38, <i>p</i> = 0.002)					
	Junior high school	OR 1.31 (1.11–1.54, <i>p</i> = 0.001)					
	Senior high school	OR 1.27 (1.09–1.48, <i>p</i> = 0.002)					
	Tertiary	OR 1.60 (1.32–1.93, <i>p</i>< 0.0001)					
Aye (2019) Myanmar. Cross-sectional. 60–106 years [25]	Educational level					Higher educational level increasing odds of multimorbidity. The prevalence of multimorbidity was lower in the participants with less than middle school education compared to the reference group of those with a diploma (adjusted prevalence ratio (aPR) 0.50, 95% CI 0.25–0.99).	Residence, sex, (level of education), smoking, drinking, general health status and involved in social activities.
	Illiterate	PR 0.48 (0.22–1.05)					
	Below Middle school	PR 0.50 (0.25–0.99)					
	Middle to High school	PR 0.60 (0.29–1.27)					
	Diploma/graduate (Reference)	PR 1.00					
Ba (2019) Central Highlands Region of Vietnam. Cross-sectional. ≥15 years [26]	Educational level					Higher educational level reducing odds of multimorbidity. "After controlling for other variables, participants who received a high school education may have lower 0.8 times of odds (95% CI 0.59–0.98) of suffer from multimorbidity compared to those with secondary or less school education.	Sex, age, (education), and employment.
	Secondary or less (Reference)	OR 1.00					
	High school	OR 0.8 (0.59–0.98)					
	University	OR 1.07 (0.72–1.60)					
Chong (2012) Singapore. Cross-sectional. ≥18 years [27]	Educational level	Any mental disorder only	Any physical disorder only	Comorbid mental-physical disorder		Higher educational level reducing odds of multimorbidity. People with secondary education had more 2.1 times of odds (95% CI 1.2,3.8) of suffering from comorbid mental and physical disorders than those with university degree but the association between poor educational attainment and comorbid mental and physical conditions was not obvious.	N/A
	Pre-primary	-	OR 1.0 (0.6–1.6, <i>p</i> >0.05)	OR 0.6 (0.2–2.1, <i>p</i> >0.05)			
	Primary	OR 0.8 (0.4–1.6, <i>p</i> >0.05)	OR 1.2 (0.8–1.7, <i>p</i> >0.05)	OR 0.8 (0.3–1.8, <i>p</i> >0.05)			
	Secondary; Pre-U/Junior	OR 1.1 (0.6–1.8, <i>p</i> >0.05)	OR 1.4 (1.1–1.9, <i>p</i><0.05)	OR 2.1 (1.2–3.8, <i>p</i><0.01)			
	College/Diploma	OR 0.8 (0.5–1.3, <i>p</i> >0.05)	OR 1.1 (0.8–1.5, <i>p</i> >0.05)	OR 1.4 (0.8–2.2, <i>p</i> >0.05)			
	Vocational	OR 0.9 (0.5–1.6, <i>p</i> >0.05)	OR 1.2 (0.8–1.7, <i>p</i> >0.05)	OR 1.4 (0.7–2.8, <i>p</i> >0.05)			
	University (Reference)	OR 1.0	OR 1.0	OR 1.0			
Ha (2015) Southern Vietnam. Cross-sectional. ≥60 years [15]	Educational level					Higher educational level reducing odds of multimorbidity. People who were literate (aOR 0.68, 95% CI 0.54–0.85) would have lower likelihood of multimorbidity after controlling for the other variables.	Age, sex, marital status, (literacy), working status, residence, drinking, smoking, BMI, basic activities for daily activity and healthcare utilisation.
	Illiterate (Reference)	OR 1.00					
	Literacy	OR 0.68 (0.54–0.85, <i>p</i> = 0.001)					
Hussain (2015) Indonesia, Cross-sectional, ≥40 years [28]	Educational level	Men		Women		Men: Higher educational level increasing odds of multimorbidity. Higher educated men had higher odds of multimorbidity. Women: No association between educational level and multimorbidity. There was no association between education and multimorbidity in women.	Age, house location, ethnicity, (education), marital status, and per capita expenditure quintiles.
	Elementary or less (Reference)	OR 1.0		OR 1.0			
	High school	OR 1.2 (1.0–1.5)		OR 1.0 (0.9–1.2)			
	Graduate and above	OR 1.5 (1.1–1.9)		OR 1.2 (0.9–1.5)			

(Continued)

Table 4. (Continued)

First author (year), Study area, Study design, Age range	The association between educational level and multimorbidity (value, (95% CI, <i>p</i> -value))			The main results of the relationship between educational level and multimorbidity	Adjusted factors
Liew (2011) Indonesia, Cross-sectional, Male: 40–93 years, Female: 40–94 years [30]	Educational level: Up to primary; Secondary; College and university	Model 1	Model 2 (Building upon the Model one to add chronic health conditions, mobility problems, age, marital status, and smoking behaviour.)	All: Higher educational level increasing odds of multimorbidity. High educated people with have higher odds of suffering from at least two chronic health conditions. Women: Higher educational level reducing odds of multimorbidity. Higher level of education was beneficial for the health of females. Women (from around 2.2 to 1.6) with a college or university education suffered from a lower number of chronic illnesses than the male counterparts (from about 1.9 to 1.75).	Mobility problems, age, marital status, and smoking.
	Education (lower education level as reference)	Coefficients: 0.141 <i>p</i> < 0.01 OR 1.151	Coefficients: 0.121 <i>p</i> < 0.05 OR 1.129		
	Female-Education (lower education level as reference)	Coefficients: −0.310 <i>p</i> < 0.001 OR 0.733	Coefficients: −0.148 <i>p</i> < 0.05 OR 0.862		
Marthias (2021) Indonesia, Cross-sectional, ≥50 years [31]	Educational level	Main results (IFLS-4 & IFLS-5)	Robustness check (IFLS-5)	Higher educational level increasing odds of multimorbidity. Main results: In the comparison with lower educational level, higher educated participants would be more likely to experience multimorbidity (aOR 1.50, 95% CI 1.12–2.02 for junior level; aOR 1.54, 95% CI 1.01–2.34 for tertiary level). Robustness check: Those people with higher education would be linked to a heavier burden of multimorbidity.	Gender, age, marital status, (education), ethnicity, insurance coverage, type of work and per capita household expenditure, residency and region.
	No education (Reference)	OR 1.00	OR 1.00		
	Primary	OR 1.19 (0.98–1.44, <i>p</i> = 0.081)	OR 1.35 (1.16–1.57, <i>p</i> < 0.01)		
	Junior high school	OR 1.50 (1.12–2.02, <i>p</i> = 0.007)	OR 1.66 (1.33–2.06, <i>p</i> < 0.01)		
	Senior high school	OR 0.96 (0.71–1.29, <i>p</i> = 0.778)	OR 1.23 (0.99–1.53, <i>p</i> > 0.05)		
	Tertiary	OR 1.54 (1.01–2.34, <i>p</i> = 0.043)	OR 1.77 (1.33–2.36, <i>p</i> < 0.01)		
Mwangi (2019) rural Northern Vietnam (FilaBavi), Cross-sectional, ≥60 years [32]	Educational level	having a common chronic disease (CCD)	having one CCD or more than one CCDs	No association between educational level and multimorbidity. Old people with high school level had more odds of one common chronic disease (CCD) (OR 2.54, 95% CI 1.13–5.74, <i>p</i> -value < 0.05). However, there was no association between education and having one CCD or more than one CCDs.	N/A
	Illiterate (Reference)	1.00	1.00		
	Read and write only	OR 1.44 (0.89–2.34, <i>p</i> = 0.141)	OR 1.1 (0.452–2.681, <i>p</i> = 0.833)		
	Primary/secondary	OR 1.38 (0.83–2.27, <i>p</i> = 0.213)	OR 0.904 (0.364–2.246, <i>p</i> = 0.828)		
	High school	OR 2.54 (1.13–5.74, <i>p</i> = 0.025)	OR 2.103 (0.555–7.959, <i>p</i> = 0.274)		
	Above high school	OR 1.93 (0.89–4.18, <i>p</i> = 0.096)	OR 0.607 (0.142–2.589, <i>p</i> = 0.5)		
Pengpid (2017) Four Greater Mekong countries: Cambodia, Myanmar, Thailand, Vietnam, Cross-sectional, 18–94 years [14]	Educational level	Two conditions vs. one condition	Three or more conditions vs. one condition	Higher educational level reducing odds of multimorbidity. In comparison with those who had only one chronic condition, Lower educated people had more odds of having multimorbidity.	Gender, age, (education), income, region, quality of life and physical inactivity.
	Grade 0–5 (Reference)	OR 1.00	OR 1.00		
	Grade 6–11	OR 0.78 (0.62–0.99, <i>p</i> < 0.05)	OR 0.44 (0.36–0.54, <i>p</i> < 0.001)		
	Grade 12 or more	OR 0.59 (0.44–0.78, <i>p</i> < 0.001)	OR 0.30 (0.23–0.39, <i>p</i> < 0.001)		
Pengpid (2021) Thailand, Cross-sectional, ≥19 years [33]	Educational level	Monk healer	Primary care	Monk healer: Higher educational level increasing odds of multimorbidity. People with post-secondary education had more odds of multimorbidity in the monk healer setting (aOR 1.68, 95% CI 1.03, 2.76). Primary care: Higher educational level reducing odds of multimorbidity. Participants with secondary education had less odds of multimorbidity of multimorbidity (aOR 0.47, 95% CI 0.29–0.75) when comparing to primary or less education in the primary care setting. All: No association between educational level and multimorbidity. There was no association between education and multimorbidity in the combination of monk healer and primary care.	Gender, age, (education), employment, marital status, economic status, comorbidity, and health care setting.
	Primary or less (Reference)	OR 1.00	OR 1.00		
	Secondary	OR 1.20 (0.74–1.95, <i>p</i> > 0.05)	OR 0.47 (0.29–0.75, <i>p</i> < 0.01)		
	Post-secondary	OR 1.68 (1.03–2.76, <i>p</i> < 0.05)	OR 0.83 (0.41–1.67, <i>p</i> > 0.05)		
Picco (2016) Singapore, Cross-sectional, Major: 60–74 years [34]	Educational level			Higher educational level reducing odds of multimorbidity. People who had secondary education would have less odds of suffering from multimorbidity (aOR 0.6, 95% CI 0.3–0.9, <i>p</i> = 0.047).	Age, sex, ethnicity, marital status, (education), and employment.
	No education (Reference)	OR 1.0			
	Some, but did not complete primary	OR 0.8 (0.5–1.3, <i>p</i> = 0.342)			
	Completed primary	OR 0.7 (0.4–1.2, <i>p</i> = 0.156)			
	Completed secondary	OR 0.6 (0.3–0.9, <i>p</i> = 0.047)			
	Completed tertiary	OR 0.6 (0.3–1.2, <i>p</i> = 0.123)			

(Continued)

Table 4. (Continued)

First author (year), Study area, Study design, Age range	The association between educational level and multimorbidity (value, (95% CI, <i>p</i> - value))			The main results of the relationship between educational level and multimorbidity	Adjusted factors
Subramaniam (2014) Singapore, Cross-sectional, ≥18 years [35]	Educational level			No association between educational level and multimorbidity. Educational level was not associated with two or more chronic medical conditions (all the <i>p</i> >0.05).	N/A
	Primary and below	OR 1.0 (0.6–1.7, <i>p</i> = 0.93)			
	Secondary	OR 1.3 (0.9–2.0, <i>p</i> = 0.23)			
	Pre-U/Junior College/Diploma	OR 0.9 (0.6–1.4, <i>p</i> = 0.61)			
	Vocational	OR 1.0 (0.6–1.8, <i>p</i> = 0.98)			
	University (Reference)	OR 1.0			
Subramaniam (2017) Singapore, Cross-sectional, ≥60 years [36]	Educational level	Model 1	Model 2 (Having two additional adjusted factors compared with Model 1: Global Cognitive Score (COGSCORE) and World Health Organization Disability Assessment Schedule II (WHODAS II))	No association between educational level and multimorbidity. There was not an association between education and comorbid depression and diabetes mellitus (DM) (all the <i>p</i> >0.05).	Model 1: Age, sex, ethnicity, marital status, (education), employment, obesity/ overweight, smoking, diabetes treatment, any other chronic condition. Model 2: Age, sex, ethnicity, marital status, (education), employment, obesity/ overweight, smoking, diabetes treatment, any other chronic condition COGSCORE and WHODAS II.
	None	OR 2.9 (0.3– 30.2, <i>p</i> = 0.379)	OR 3.4 (0.6–18.7, <i>p</i> = 0.167)		
	Some, but did not complete primary	OR 0.6 (0.1– 5.4, <i>p</i> = 0.608)	OR 1.1 (0.2–6.1, <i>p</i> = 0.871)		
	Completed primary	OR 0.8 (0.1– 7.2, <i>p</i> = 0.806)	OR 1.3 (0.2–8.5, <i>p</i> = 0.795)		
	Completed secondary	OR 0.7 (0.1– 4.1, <i>p</i> = 0.708)	OR 0.8 (0.2–3.0, <i>p</i> = 0.749)		
	Completed tertiary (Reference)	OR 1.00	OR 1.00		
	Tiptaradol (2012) Thailand, Cross-sectional, ≥15 years [37]	Educational level	Compared to those suffering from either diabetes or hypertension alone		
No formal education (Reference)		OR 1.00			
Less than 6 years		OR 1.83 (1.03, 3.38)			
Secondary		OR 0.96 (0.54, 1.72)			
University		OR 1.06 (0.56, 2.01)			
Hussin (2019) Malaysia, Longitudinal, (0.5-year follow-up), ≥60 years [29]	Educational level: No schooling; 1–6; 7–11; 12 years and above	No disease at baseline	One disease at baseline	No association between educational level and multimorbidity. Without any disease at baseline showed that education was not related to multimorbidity incidence at follow-up (<i>p</i> >0.05). With one disease at baseline showed that education was not related to multimorbidity incidence at follow-up (<i>p</i> >0.05).	Without any disease at baseline: age, gender, (education), smoking, cognitive and lifestyle. With one disease at baseline: age, sex, (education), BMI, glucose, cognitive and dietary intake.
	0–6 years	OR 1.296 (0.555–3.027, <i>p</i> = 0.549)	OR 0.584 (0.320–1.064, <i>p</i> = 0.079)		
	7 and above (Reference)	OR 1.000	OR 1.000		

Bolded font of number indicated a significant difference.

N/A: Not available.

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Confidence interval (CI) 0.59–0.98). Furthermore, in the other study focused on the population older than 60 years in southern Vietnam [15], literate individuals (aOR 0.68, 95% CI 0.54–0.85) were associated with lower odds of multimorbidity in comparison with illiterate individuals after controlling for the related confounders (Table 4).

Higher education increasing odds of multimorbidity

Seven cross-sectional studies found education has been associated with increasing odds of multimorbidity [24,25,28,30,31,33,37] and four of these studies [24,28,30,31] were located in Indonesia. Anindya *et al* [24] showed that higher educated people (more than 40-year-old) had more odds of suffering from multimorbidity after controlling for socio-demographic variables (all p -value > 0.05). Moreover, in another study in Indonesia [31], comparing lower

levels of education to high level of education, 50-year-old and older participants would be more likely to suffer from multimorbidity. Furthermore, another study in Thailand [37] showed, after adjusting for potential confounders for socio-demographic variables, those 15 years old and older with less than 6 years of education (aOR 1.83, 95% CI 1.03–3.38) were more likely to have multimorbidity compared to those with no formal education (Table 4).

Education having no association with multimorbidity

There were eight studies (including the only longitudinal study) which showed no association among educational attainment and multimorbidity [16,23,28,29,32,33,35,36]. Three cross-sectional studies [23,35,36] were located in Singapore. For instance, one study [35] showed that the odds of having multiple chronic medical conditions were not associated with educational attainment, but this study did not control for relevant confounders. Furthermore, in other countries like Laos, Malaysia, Myanmar, and Philippines [16], the results showed that educational levels were not associated with multimorbidity in these four countries after controlling for gender and age (all p -value > 0.05) (Table 4).

Discussion

This was the first study to systematically review and assess the available literature on the prevalence of multimorbidity and the relationship between education level and multimorbidity in Southeast Asia.

We identified a small number of relevant publications and found heterogeneity between these studies. For example, the estimation of sample size, the grouping of education levels, the age groups of study participants, and the inclusion and exclusion criteria varied considerably among the studies we included, making comparability difficult [18] that did not allow us to clarify the association between education level and multimorbidity using meta-analysis.

There were two obvious associations between education and multimorbidity in Singapore and Indonesia, respectively. Firstly, educational level was not associated with multimorbidity in Singapore, alternately higher levels of education were associated with higher odds of developing multimorbidity in Indonesia. The reasons for these results may be related to differences in the purpose and methods of these studies, such as different patterns of multimorbidity, classification of education levels, and the confounding factors, and may also be related to the databases used in these studies.

Most studies in Singapore [23,35,36] mentioned that education level was not associated with multimorbidity. According to the authors, this is likely to be related to the fact that these studies [23,27,34–36] from Singapore used only two databases, the Singapore Mental Health Study (SMHS) [23,27,35] and the Wellbeing of the Elderly in Singapore (WiSE) [34,36]. It may be that the association between education level and multimorbidity was not significant in these two databases [23,27,34–36]. In addition, it is worth noting that the results would be influenced by many factors, even when a common data source was used for the analysis, the definition of multimorbidity, adjustment factors, and differences in education level, may impact on the results. For example, the study of Chong *et al* [27] and the study of Subramaniam *et al* [35] used the SMHS-2010, but the classification of education level (the study of Subramaniam *et al* [35] combining the level of Pre-U/Junior College/Diploma together) and the pattern of multimorbidity differed (the pattern of multimorbidity including mental disorders in the study of Chong *et al* [27]), thus the results of the connection of multimorbidity and education of these two studies were different. Similarly, the study of Picco *et al* [34] and the study of Subramaniam *et al* [36] used WiSE, but their patterns of multimorbidity and adjustment

factors were very different, leading to distinct results of the association between educational level and multimorbidity.

While all four Indonesia studies found [24,28,30,31] that higher education levels were associated with higher odds of developing multimorbidity, all of them used the Indonesian Family Life Survey (IFLS). It was likely that the association between higher education level and higher odds of developing multimorbidity was evident in the IFLS database. However, there were still many differences between the results of these studies. The reasons for this include factors such as the purpose of the study, the selection of the population, and the method of analysis affected the association between multimorbidity and education level. Also relevant was that the IFLS is a longitudinal study collecting data every 4–5 years. The various studies using IFLS data conducted cross sectional analysis on various waves of this study, which may also help explain the variation. A typical example was the study by Marthias *et al* [31]. This study consisted of two cross-sectional sub-studies whose purpose and methods were consistent. However, the difference in the pattern of multimorbidity and participants between these two sub-studies made the results of the association between multimorbidity and education level different [31].

High levels of education have been reported to reduce the odds of developing multimorbidity in western countries such as the United States and Canada [8]. However, in some studies of LMICs, the relationship between education level and multimorbidity was more complex than in developed countries. For example, in some studies from Bangladesh [38], India [39–41] and China [42,43], there was a positive [38,39,42], negative [40,43] or no association [41] between high education level and higher odds of multimorbidity. This was the same the results of our study.

The improvement of educational level was recognized as reducing risk of multimorbidity [10,44]. The potential reason would be that as the level of education increased, people's SES would also increase, making them more aware of healthy living and gaining health literacy and decreasing the risk [8,10,44]. In developed countries such as the United States and Canada, people with low SES were more likely to suffer from multimorbidity due to their lack of health knowledge, higher stress levels, and inability to afford healthy and adequate diet, which made them less healthy [8,10]. At the same time, their inability to afford the high cost of medical care after suffering from multiple diseases caused their health level to further worsen, which would be a vicious cycle [8,10]. The same problem was faced in developing countries. However, few studies have investigated multimorbidity in depth in developing countries, and the current focus in developing countries was still on single diseases [9,18]. This was because although aging has been also increasing in LMICs, the proportion of the elderly population is relatively low compared to that in developed areas, and aging is positively correlated with the incidence of multimorbidity [2,3,5]. These have led to under-research of multimorbidity in LMICs and a great variation from study to study, resulting in a diversity of results between multimorbidity and factors such as education level.

Several studies have shown that higher levels of education increase the chances of developing multimorbidity, and the reasons for this phenomenon include the following. Firstly, although people of lower educational level in LMICs were more likely to consume a poor diet quality—low in fruit and vegetables and high in red meat and processed food—higher educated people tended to favour sedentary lifestyle habits, thus increasing the odds of developing multimorbidity [38]. In addition, people with higher levels of education had better access to medical care and better health knowledge, especially in developing countries. Since people with low SES in developing countries had more difficulty accessing effective medical care with relevant health knowledge compared to their counterpart in high-income countries [24,38]. These highly educated people were more likely to receive a diagnosis of their condition and to be reported as having chronic conditions [24]. As for the results of no association between

education and multimorbidity, it may be due to information bias in the study itself, selection bias, and confounding factors that have an impact on the results [35,41].

Most studies in this review did not describe the criteria for selecting chronic conditions [18,22]. Most common was selection of common or high prevalence diseases for inclusion in the study. For example, some studies included infectious diseases such as tuberculosis (TB) [15,28–30] and mental diseases [14,16,23–28,31,33,34,36], and the definition of multimorbidity in four [23,27,36,37] studies was two comorbid conditions. Because the number and type of chronic diseases determined the estimates of multimorbidity, prevalence rates and associations with education differed [18,22]. What is more, differences in study location, size and characteristics of the study population, data collection methods, and educational attainment classification may lead to selection bias and thus to different results [18,22]. Different data collection methods could also result in bias, and the recall bias of self-report could be more pronounced compared to medical examination for the identification of multimorbidity. In addition, different confounders had a significant impact on the results. For example, education level can be confounded by other socio-demographic factors including age, gender, and income [18,19,22]. Generally, the older age of the studied population implied a higher prevalence of multimorbidity, as we found in this paper [2,3,5,45]. As for the classification of educational attainment, the same data using different classifications of educational attainment could also lead to differences in the results that emerged, such as in the two studies [23,27] in Singapore.

Strength and limitation

The main strength of this paper included the systematic listing of education level separately in relation to multimorbidity, rather than including it in the SES, which provided a more precise understanding of the association between education level and multimorbidity.

The results of most studies [16,32,33,35] obtained with self-report data showed no association between education level and multimorbidity, and the sample size and age range of these studies varied widely, suggesting that such results may be related to self-reported having recall bias. The studies of multimorbidity tended to favour objective test of multimorbidity such as physical examination, or a combination of physical examination (major) and self-report (minor), because this could reduce the bias in the outcomes. In addition, in studies with participants older than 40 years, most of the results [24,25,28,30,31] showed that high education level was associated with high odds of having multimorbidity. This may be due to the same set of datasets used in number of these studies [24,28,30,31]. We did not find a pattern in the effect of sample size on the results. However, in general, the larger the sample size, the more accurate the results should be, controlling for other variables such as age and data collection [8,19,22].

The differences in inclusion and exclusion criteria for chronic diseases, sample size estimates, differences in study areas, different age groups of study participants, differences in data collection methods, distinction in educational level groupings, differences in confounding factors may all lead to large biases across studies and, to some extent, explain the large differences in observed outcomes. The inherent bias in the estimates of the original studies prevented the assessment of the quantification of prevalence of multimorbidity and the estimation of the association between education level and multimorbidity. The similar heterogeneity was seen in the systematic review of studies on the prevalence of multimorbidity in South Asia [18], with different methodologies and research settings contributing to this phenomenon.

Additionally, there are seventeen cross-sectional studies but only one longitudinal study. The lack of longitudinal studies made it impossible to definitively state whether there was a causal relationship between education level and multimorbidity [22,45].

Another limitation was that it was difficult to ensure that all relevant literature was included. Since multimorbidity was not well indexed in literature databases and was often used interchangeably with the term “comorbidity” [18,22]. Although the term “comorbidity” was also searched separately in the database after the initial search to compensate for this search omission, inadvertent omissions could not be excluded [22]. In addition, other keywords such as “education level” and “Southeast Asia” may have other names that we did not mention, and some literature may have been omitted. An inherent limitation of any systematic review was the limitation of the search period, which in our case was from January 1, 1990, to June 15, 2021, implying the exclusion of new studies after the end date, which may have led to the omission of more recent studies [18]. We also restricted the search to English publications, resulting in relevant articles in other languages that we could not retrieve [18,22]. Furthermore, another major limitation was the large amount of statistical and methodological heterogeneity, causing the inability to combine studies to obtain overall estimates of prevalence in multimorbidity and the overall estimates of association of education level with multimorbidity [18].

Implications for policy, practice, and future research

The Association between multimorbidity and education remains an underappreciated area of research in Southeast Asia. As mentioned above, the small number of relevant studies included in this article and the large differences of statistics and methodology between individual studies. The results of the available global systematic review [8] on SES and multimorbidity suggest that the higher the level of education is, the lower the odds of developing multimorbidity people have. Although this result is inconsistent with the association between multimorbidity and education in Southeast Asia derived in this paper, the salient heterogeneity of this study imposes limitations on the overall estimation of the connection between education level and multimorbidity to calculate a uniform association. Therefore, in the next studies in Southeast Asia, the panel of chronic conditions should be prepared with a standardized definition of each disease and a uniform operational definition of multimorbidity, which could reduce the selection bias of chronic conditions and lead to a more reliable and comparable estimate of multimorbidity [18,22]. In addition, there should be uniform and objective criteria for the classification of education level, such as no education; elementary school; middle school, junior high school, high school, university, or higher, and reducing self-reported data collection methods and strengthening objective tests, such as physical examinations, would also bring accurate results.

Conclusion

This study is a comprehensive mapping of research related to the association between education and multimorbidity in the Southeast Asian region and reveals the neglect and lack of studies on the connection between multimorbidity and educational level in this region. The heterogeneity of the findings did not allow us to reach a definitive conclusion about the association between educational level and multimorbidity. The prevalence of multimorbidity ranged widely in this study, and the associations between educational attainment and multimorbidity were inconsistent. Reasons for this result include the different national contexts and the lack of relevant studies on the relationship between educational status and multimorbidity in Southeast Asian countries. This study may indicate the need to reduce the use of subjective data collection methods, such as self-report, to improve credibility and accuracy when studying the relationship between multimorbidity and education. Finally, there were several different connections between educational attainment and multimorbidity in Southeast Asia in this paper,

however, it is predicted that a sound and completed educational system could help people to raise health awareness and thus effectively prevent multimorbidity.

Supporting information

S1 Table. Search query of databases.

(DOCX)

S2 Table. NOS checklist for selected studies (cross-sectional study).

(DOCX)

S3 Table. PRISMA 2009 checklist.

(DOC)

S1 File. The PROSPERO-registered number-CRD42021259311.

(PDF)

S2 File. The Newcastle-Ottawa Scale (NOS) checklist.

(PDF)

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S1 Table Search query of databases.

Database	Search query	Results
Scopus	TITLE-ABS-KEY ("multi-morbidity" OR "multimorbidity" OR "multi-morbidities" OR "multimorbidities" OR "multimorbid" OR "multiple morbidities" OR "multiple morbidity" OR "multiple conditions" OR "multiple diseases" OR "multiple chronic diseases" OR "multiple chronic conditions" OR "multiple illnesses" OR "multiple diagnoses" OR "multi-pathology" OR "co-morbid" OR comorbidity OR "co-morbidity" OR "co-morbidities" OR "comorbidities") AND ALL (education OR literacy OR "educational status" OR "educational level" OR "educational attainment") AND ALL ("Southeast Asia" OR "Association of Southeast Asian Nation" OR "ASEAN" OR brunei OR cambodia OR "East Timor" OR indonesia OR laos OR malaysia OR myanmar OR philippines OR singapore OR thailand OR vietnam) AND (LIMIT-TO (LANGUAGE , "English"))	3955
PubMed	(("multi-morbidity"[Title/Abstract] OR "multimorbidity"[Title/Abstract] OR "multi-morbidities"[Title/Abstract] OR "multimorbidities"[Title/Abstract] OR "multimorbid"[Title/Abstract] OR "multiple morbidities"[Title/Abstract] OR "multiple morbidity"[Title/Abstract] OR "multiple conditions"[Title/Abstract] OR "multiple diseases"[Title/Abstract] OR "multiple chronic diseases"[Title/Abstract] OR "multiple chronic conditions"[Title/Abstract] OR "multiple illnesses"[Title/Abstract] OR "multiple diagnoses"[Title/Abstract] OR "multi-pathology"[Title/Abstract] OR "co-morbid"[Title/Abstract] OR comorbidity OR "co-morbidity"[Title/Abstract] OR "co-morbidities"[Title/Abstract] OR "comorbidities"[Title/Abstract]) AND (education OR literacy OR "educational status" OR "educational level" OR "educational attainment")) AND ("Southeast Asia" OR "Association of Southeast Asian Nation" OR "ASEAN" OR brunei OR cambodia OR "East Timor" OR indonesia OR laos OR malaysia OR myanmar OR philippines OR singapore OR thailand OR vietnam) Filters: English, from 1990/1/1 - 2021/6/15	591
ProQuest	ab("multi-morbidity" OR "multimorbidity" OR "multi-morbidities" OR "multimorbidities" OR "multimorbid" OR "multiple morbidities" OR "multiple morbidity" OR "multiple conditions" OR "multiple diseases" OR "multiple chronic diseases" OR "multiple chronic conditions" OR "multiple illnesses" OR "multiple diagnoses" OR "multi-pathology" OR "co-morbid" OR comorbidity OR "co-morbidity" OR "co-morbidities" OR "comorbidities") AND (education OR literacy OR "educational status" OR "educational level" OR "educational attainment") AND ("Southeast Asia" OR "Association of Southeast Asian Nation" OR "ASEAN" OR Brunei OR Cambodia OR "East Timor" OR Indonesia OR Laos OR Malaysia OR Myanmar OR Philippines OR Singapore OR Thailand OR Vietnam) Limitation: 1990-01-01 - 2021-06-15; English	3012

Exposure	Outcome	Location
education, literacy, educational status, educational level, educational attainment	multi-morbidity, multimorbidity, multimorbid, multiple morbidities, multiple morbidity, multiple conditions, multiple diseases, multiple chronic diseases, multiple chronic conditions, multiple illnesses, multiple diagnoses, multi-pathology	Southeast Asia, Association of Southeast Asian Nation, ASEAN, Brunei, Cambodia, East Timor, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam

S2 Table NOS Checklist for selected studies (cross-sectional study).

Study (First author (year)) Cross- sectional (Total ten scores)	Selection												Comparability			Outcome							Total scores for all	Level	
	Representativeness				Sample size		Non-respondents			Ascertainment (risk factor)			Total scores	On the basis of the study design or analysis and the control of confounders		Total scores	Assessment				statistical test				Total scores
	Truly representative (1)	Somewhat representative (1)	Selected group (0)	No description (0)	Justified (1)	Not justified (0)	Satisfactory (1)	Unsatisfactory (0)	No description (0)	Validated (1)	Non- validated (0)	No description (0)		Most important factor (1)	Any additional factor (1)		Independent blind assessment (1)	Record linkage (1)	Self- report (0)	No description (0)	clearly described & appropriate (1)	not appropriate or described (0)			
Abdin (2020) [23]	1				1			0		1			3		1	1		1	0		1		2	6	Fair
Afshar (2015) [16]	1				1		1			1			4	1		1			0		1		1	6	Fair
Anindya (2020) [24]	1				1		1			1			4		1	1		1	0		1		2	8	Good
Aye (2019) [25]	1				1		1			1			4		1	1			0		1		1	6	Fair
Ba (2019) [26]	1				1		1			1			4		1	1			0		1		1	6	Fair
Chong (2012) [27]	1				1		1			1			4			0		1	0		1		2	6	Poor
Ha (2015) [15]	1				1		1			1			4		1	1		1			1		2	7	Good
Hussain (2015) [28]	1				1		1			1			4		1	1		1	0		1		2	7	Good
Liew (2011) [30]		1			1		1			1			4	1	1	2		1			1		2	8	Good
Marthias (2021) [31]		1			1		1			1			4		1	1		1	0		1		2	7	Good
Mwangi (2019) [32]	1				1			0		1			3			0			0		1		1	4	Poor
Pengpid (2017) [14]		1			1			0		1			3		1	1		1			1		2	6	Fair
Pengpid (2021) [33]		1				0	1			1			3		1	1			0		1		1	5	Fair
Picco (2016) [34]	1				1		1			1			4		1	1			0		1		1	6	Fair
Subramaniam (2014) [35]	1				1		1			1			4			0			0		1		1	5	Poor
Subramaniam (2017) [36]	1				1		1			1			4	1	1	2		1	0		1		2	8	Good
Tiptaradol (2012) [37]		1			1			0		1			3		1	1		1			1		2	6	Fair

S2 Table NOS Checklist for selected studies (cohort study).

Study (first author (year)) Longitudinal (Total nine scores)	Selection													Comparability			Outcome													Total scores for all	Level
	Representativeness				Non exposed cohort			Ascertainment				Demonstration		Total score	On the basis of the design or analysis		Total score	Assessment				Long enough follow-up		Adequacy				Total score			
	Truly representative (1)	Somewhat representative (1)	selected group (0)	No description (0)	Same community (1)	Different source (0)	No description (0)	Secure record (1)	structured interview (1)	Written self - report (0)	No description (0)	Yes (1)	No (0)		Most important factor (1)	Any additional factor (1)		Independent blind (1)	Record linkage (1)	Self- report (0)	No description (0)	Yes (1)	No (0)	complete follow up (1)	subjects lost to follow up (1)	No description of those lost (0)	no statement (0)				
Hussein (2020) [29]	1				1					0		1		3		1	1			0		0		1				1	5	Fair	



PRISMA 2009 Checklist

S3 Table PRISMA 2009 Checklist.

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title p.1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract p.2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Introduction p.4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	Introduction p.4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Methods p. 6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	Methods p. 6-7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Methods pp.7-10
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	S1 Table
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Methods pp.7-10
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Methods pp.8-10 (Table 1 & 2)
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Table 3



PRISMA 2009 Checklist

Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Methods pp.10-11 and S2 Table
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Methods pp.10-11
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	Methods pp.10-11, p.29

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Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	Results pp.11-15
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	–
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig. 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 3
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Table 3 & 4
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Table 4
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	–
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Results pp.11-15
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	–
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Discussion pp.15-21
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Discussion pp.19-21



PRISMA 2009 Checklist

Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Conclusion p. 21-22
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	–

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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To enable PROSPERO to focus on COVID-19 submissions, this registration record has undergone basic automated checks for eligibility and is published exactly as submitted.

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Citation

Xiyu Feng, Matthew Kelly, Haribondhu Sarma. The association between educational level and multi-morbidity of non-communicable diseases (NCDs) among adults in Southeast Asia: Systematic Review. PROSPERO 2021 CRD42021259311 Available from:

https://www.crd.york.ac.uk/prospERO/display_record.php?ID=CRD42021259311

Review question

What are the joint prospective associations between educational level with the outcomes of the prevalence of multi-morbidity of non-communicable diseases among adults in Southeast Asia?

Searches

I plan to use the five databases, namely, PubMed, ANU library, Scopus and Cochrane Library and Web of Science. No restriction of publication date but the literature must be English.

Types of study to be included

Cross-sectional, cohort and longitudinal study.

Condition or domain being studied

Multi-morbidity of non-communicable disease is defined as a person suffering from two or more chronic non-communicable diseases at the same time. Although the prevalence of multi-morbidity is relatively low in developing countries such as Thailand, ranging from 14% to 68%, compared to developed countries (14% to 90%), it is due to the substantial decline in mortality in childhood and childbirth and mortality of infectious diseases in these countries and the continued increase in the average life expectancy of the population. However, as aging is increasing in Southeast Asia, multi-morbidities and co-morbidities are becoming more common.

Participants/population

The study population of this topic will focus on the studies done on the adults in Southeast Asia (including Brunei, Philippines, Singapore, Vietnam, Laos, Cambodia, Thailand, Myanmar, Malaysia, Timor-Leste).

Intervention(s), exposure(s)

The level of education, as one of the factors of socioeconomic status (SES), is very important for the health of the population. This is because contemporary society is an information and a knowledge economy society. A higher level of education means that people will have more chances to find good jobs, better living environment, better eating habits, more attention to their health and thus health level will increase. Therefore, the purpose of taking the level of education above secondary school as exposure is to investigate whether higher education level will reduce the prevalence of multi-morbidity/comorbidity of non-communicable diseases among Southeast Asia.

Comparator(s)/control

The reason why illiterate or below secondary school level people are used as a control is because the living environment of this group of people is generally not as friendly as those with higher education and they are also more prone to various diseases and have a higher chance of suffering from multi-morbidity/comorbidity of non-communicable diseases.

Main outcome(s)

Multi-morbidity and comorbidity of non-communicable disease.

Additional outcome(s)

None.

Data extraction (selection and coding)

As for the assessing of the literature, we should use the JBI Critical Appraisal Tools to check the trustworthiness of literature which will be in the systematic review. This data and information can be listed in the table. The table of each article can contain the following messages such as (1) Author, Year, (2) Country, (3) Study type, (4) Study Population, (5) Male %/Age (years), (6) Definition of Multi-morbidity/Comorbidity of non-communicable diseases/NCDs, (7) Ascertainment of morbidities, and (8) results. Then, the data extraction results should be submitted to a third-party review.

Risk of bias (quality) assessment

The potential limitations are mainly reflected in the following aspects. The first is that some database access is difficult, which leads to the inability to retrieve some articles, reducing the validity of the outcomes. Secondly, there is a lack of literature published in related fields, making it hard to extract valid data for evaluation and analysis. Thirdly, the heterogeneity of the studies included is also a limitation since multi-morbidity or comorbidity of non-communicable disease is defined and measured in different ways in different studies. These limitations may lead to a decrease in the reliability and validity of the systematic review. Thus, in practice, these limitations should be avoided as much as possible.

Strategy for data synthesis

The qualitative study should be used narrative synthesis, which included the definition of multi-morbidity and comorbidity of non-communicable disease. And the quantitative analysis should be used on prevalence of the multi-morbidity and comorbidity of non-communicable disease and the association between educational level and multi-morbidity/comorbidity among adults. If the sources of data found in the literature are similar, e.g., questionnaires or clinical data, then quantitative analysis can use meta-analysis. However, if the sources of data in the literature are very different, meta-analysis may not be used.

Analysis of subgroups or subsets

Qualitative study: Because different articles have different definitions of non-communicable disease comorbidity and multi-morbidity, and these definitions are narrative, this section uses narrative synthesis to summarize the definition of non-communicable disease multi-morbidity and comorbidity.

Quantitative analysis: As for the prevalence of the multi-morbidity and comorbidity of non-communicable disease and the association between educational level and non-communicable disease multi-morbidity/comorbidity among adults, it should be synthesized by cross-sectional, cohort and longitudinal studies. If the sources of data in the literature are heterogeneous, meta-analysis may not be used.

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Type and method of review

Systematic review

Anticipated or actual start date

07 June 2021

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06 September 2021

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Language

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Review Ongoing

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Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	No
Piloting of the study selection process	Yes	No
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

The record owner confirms that the information they have supplied for this submission is accurate and complete and they understand that deliberate provision of inaccurate information or omission of data may be construed as scientific misconduct.

The record owner confirms that they will update the status of the review when it is completed and will add publication details in due course.

Versions

08 July 2021

08 July 2021

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE

CASE CONTROL STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

Selection

1) Is the case definition adequate?

- a) yes, with independent validation *
- b) yes, e.g. record linkage or based on self-reports
- c) no description

2) Representativeness of the cases

- a) consecutive or obviously representative series of cases *
- b) potential for selection biases or not stated

3) Selection of Controls

- a) community controls *
- b) hospital controls
- c) no description

4) Definition of Controls

- a) no history of disease (endpoint) *
- b) no description of source

Comparability

1) Comparability of cases and controls on the basis of the design or analysis

- a) study controls for _____ (Select the most important factor) *
- b) study controls for any additional factor * (This criteria could be modified to indicate specific control for a second important factor.)

Exposure

1) Ascertainment of exposure

- a) secure record (e.g. surgical records) ✱
- b) structured interview where blind to case/control status ✱
- c) interview not blinded to case/control status
- d) written self-report or medical record only
- e) no description

2) Same method of ascertainment for cases and controls

- a) yes ✱
- b) no

3) Non-Response rate

- a) same rate for both groups ✱
- b) non respondents described
- c) rate different and no designation

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE

COHORT STUDIES

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Outcome categories. A maximum of two stars can be given for Comparability

Selection

1) Representativeness of the exposed cohort

- a) truly representative of the average _____ (describe) in the community *
- b) somewhat representative of the average _____ in the community *
- c) selected group of users e.g. nurses, volunteers
- d) no description of the derivation of the cohort

2) Selection of the non-exposed cohort

- a) drawn from the same community as the exposed cohort *
- b) drawn from a different source
- c) no description of the derivation of the non-exposed cohort

3) Ascertainment of exposure

- a) secure record (e.g. surgical records) *
- b) structured interview *
- c) written self-report
- d) no description

4) Demonstration that outcome of interest was not present at start of study

- a) yes *
- b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis

- a) study controls for _____ (select the most important factor) *

b) study controls for any additional factor ✱ (This criteria could be modified to indicate specific control for a second important factor.)

Outcome

1) Assessment of outcome

a) independent blind assessment ✱

b) record linkage ✱

c) self-report

d) no description

2) Was follow-up long enough for outcomes to occur

a) yes (select an adequate follow up period for outcome of interest) ✱

b) no

3) Adequacy of follow up of cohorts

a) complete follow up - all subjects accounted for ✱

b) subjects lost to follow up unlikely to introduce bias - small number lost - > ____ % (select an adequate %) follow up, or description provided of those lost) ✱

c) follow up rate < ____% (select an adequate %) and no description of those lost

d) no statement

NEWCASTLE - OTTAWA QUALITY ASSESSMENT SCALE

(adapted for cross-sectional studies)

Selection: (Maximum 5 stars)

1) Representativeness of the sample

- a) Truly representative of the average in the target population ✱ (all subjects or random sampling)
- b) Somewhat representative of the average in the target population ✱ (non-random sampling)
- c) Selected group of users
- d) No description of the sampling strategy

2) Sample size

- a) Justified and satisfactory ✱
- b) Not justified

3) Non-respondents

- a) Comparability between respondents and non-respondents' characteristics is established, and the response rate is satisfactory ✱
- b) The response rate is unsatisfactory, or the comparability between respondents and non-respondents is unsatisfactory
- c) No description of the response rate or the characteristics of the responders and the non-responders

4) Ascertainment of the exposure (risk factor)

- a) Validated measurement tool ✱
- b) Non-validated measurement tool, but the tool is available or described
- c) No description of the measurement tool

Comparability: (Maximum 2 stars)

1) The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled

- a) The study controls for the most important factor (select one) ✱
- b) The study control for any additional factor ✱

Outcome: (Maximum 3 stars)

1) Assessment of the outcome

a) Independent blind assessment ✱

b) Record linkage ✱

c) Self-report

d) No description

2) Statistical test

a) The statistical test used to analyse the data is clearly described and appropriate, and the measurement of the association is presented, including confidence intervals (CI) and/or the probability level namely, p -value ✱

b) The statistical test is not appropriate, not described or incomplete

This scale was adapted from the Newcastle-Ottawa Quality Assessment Scale for cohort and case-control studies to perform a quality measurement of cross-sectional studies for the systematic review, namely, “The association between educational level and multimorbidity among adult in Southeast Asia: Systematic review”.

This scale applied to cross-sectional studies was a modified version of the NOS scale to properly assess the quality of cross-sectional studies. We did not select a factor that was most important for Comparability, as was done for the NOS checklist for case-control studies and cohort studies, because the variables in each study were different.

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Chapter 5 The age and gender differences in patterns of multimorbidity in Thailand

This study followed directly from the systematic review of multimorbidity in Southeast Asia presented in the previous chapter. Thailand was chosen as the focus for further investigation for two main reasons. First, comprehensive and nationally representative longitudinal data were available through the Thai Cohort Study, which provided a unique opportunity to examine multimorbidity in detail. Second, Thailand is a large middle-income country in Southeast Asia that is experiencing rapid demographic and epidemiological transitions, which makes it broadly representative of regional trends.

The objective of this study was to investigate the prevalence and the common patterns of multimorbidity within various age groups and genders among the Thai population by utilizing data from the Thai Cohort Study. By undertaking this analysis, we aimed to provide valuable insights for healthcare policymakers and researchers. The focus on age and gender in this chapter is grounded in their established public health significance. Age is a fundamental determinant of multimorbidity, while gender differences influence disease burden, health-seeking behaviour, and access to care.

Understanding the patterns of multimorbidity is crucial because it enables the development of targeted and effective preventive and therapeutic strategies. By identifying prevalent multimorbidity patterns, this research contributes to the refinement of healthcare policies and the improvement of clinical practices, which ultimately facilitates better management of complex health conditions within the Thai population.

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Statement of Contribution

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

Title: Impact of age and gender differences in the prevalence and patterns of multimorbidity in the Thai Cohort Study

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Impact of age and gender differences in the prevalence and patterns of multimorbidity in the Thai Cohort Study

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Background: The study aims to identify the common patterns of multimorbidity and their distribution by age and gender.

Method: This cross-sectional study collected self-reported data from 42 785 Thai Cohort Study members through mailed questionnaires. Employing prevalence-based analysis, it identified common multimorbidity (co-existence of two or more chronic conditions) patterns, analysing the three most common patterns stratified by age and sex. P for trend (p-trend) was used to test the linear trend for associations between age and prevalence of these chronic conditions in the multimorbidity patterns.

Results: Chronic conditions with the highest prevalence were related to metabolic syndromes: obesity (28.5%), hyperlipidaemia (13.2%) and hypertension (7.2%). A positive linear age–multimorbidity association was observed (p-trend = 0.0111). The 60+ participants averaged 1.20 diseases, with 33.7% multimorbidity prevalence. Hyperlipidaemia + obesity was most prevalent in the under-40 multimorbid group (38.7%). Men exhibited a higher prevalence of multimorbidity and associated patterns involving hypertension, hyperlipidaemia and obesity than women.

Conclusion: Metabolic syndrome components were the prominent factors driving multimorbidity. Significant age and gender differences were also revealed in multimorbidity prevalence. People aged 60+ faced high risk of multimorbidity, while younger individuals tended towards the multimorbidity pattern of obesity and hyperlipidaemia. Men were more susceptible to multimorbidity patterns associated with metabolic syndromes. Future studies for metabolic-related multimorbidity should consider these differences, addressing age and gender issues.

Keywords: Age, chronic conditions, gender, multimorbidity.

Introduction

Multimorbidity, where the same person has two or more chronic health problems at the same time, is a growing global burden, and ageing is the most important risk factor.^{1,2} In Southeast Asia, the burden of non-communicable diseases (NCDs) has risen as economic levels have improved and life expectancy has increased. Ageing populations are also more likely to experience multimorbidity, which has led to a gradual increase in global prevalence from roughly 4.5% at the beginning of the twenty-

first century to 10% currently.³ A study from Indonesia showed a prevalence of about 20.8% in 2014.⁴

Effective prevention and treatment can only be carried out if the patterns of multimorbidity are identified. Currently, common multimorbidity patterns include cardiometabolic multimorbidity, mental-physical multimorbidity, metabolic conditions and cancer, which may be related to ageing and changes in lifestyle.^{1,5,6} However, in the countries of Southeast Asia, studies of these patterns of multimorbidity are relatively scarce.^{1–3}

Like other countries in Southeast Asia, after more than half a century of change from agrarian to industrialization, the population in Thailand is undergoing a health transition. NCDs have replaced infectious diseases as the number one killer of Thai people.⁷ Chronic conditions associated with metabolic syndromes, including obesity, hyperlipidaemia and hypertension, are becoming increasingly common, as are NCDs including cardiovascular diseases (CVDs) and diabetes. For example, from 2005 to 2019, disability-adjusted life year (DALY) loss due to CVDs increased by about 480 000, and DALY loss due to diabetes increased by about 370 000.⁸ However, there is a lack of research on multimorbidity in Thailand, with most studies focusing on single or specific diseases, while the presence of unrelated or uncoordinated multiple chronic diseases has not been studied in detail.³⁻⁶

The purpose of this paper is to improve understanding of the prevalence of multimorbidity and the common patterns of multimorbidity in different ages and genders in Thailand. It may help health-care decision-makers and researchers in better understanding the co-occurrence of diseases to design appropriate and targeted prevention and treatment to deal with multimorbidity.

Materials and Methods

The study sample

The Thai Cohort Study

The Thai Cohort Study (TCS), was established in 2005, studying 87 134 Thais (aged 15–87 years old) enrolled at Sukhothai Thammathirat Open University (STOU) who lived across the country. The only participant criterion was to be registered students of STOU.⁹⁻¹¹ Sampling method, sample size calculation and design effect are not applicable to the TCS. The TCS was a study where the questionnaires were distributed to a population of around 200 000 students from STOU. The objective was to include as many participants as possible to ensure comprehensive coverage.⁹ The students who responded (around 45%) formed the baseline cohort study group. The main aim of this study was to identify relationships between exposures and outcomes in the cohort (internal validity) rather than claiming that the results represent prevalence levels in the general Thai population (external validity). Our study is based on this 2013 endpoint of the TCS.⁹

Our study primarily relies on the data collection methods and overall research design of the TCS.⁹ This study is a cross-sectional analysis of 42 785 respondents who completed the final questionnaire in the TCS in 2013. As well as information on diagnosis with chronic conditions, the extracted data included age (divided into three groups: up to 39 y, 40–59 y, and ≥60 y) and gender (male and female).

Multimorbidity prevalence and patterns

In the 2013 mail-in questionnaire, one of the questions was whether respondents had been diagnosed by a doctor with any of the 11 chronic diseases listed, with those who had these diseases reporting ‘yes’ and those without them reporting ‘no’.⁹ Furthermore, participants also self-reported their weight and height, and body mass index (BMI) was calculated from these two variables.

Table 1. Characteristics of the study population of multimorbidity in the Thai Cohort Study in 2013

	Number of people (n)	People with multimorbidity (n)	Proportion (%) (95% CI)
Male	19 330	2863	14.8 (14.3 to 15.3)
≤39 y	8251	530	6.4 (5.9 to 7.0)
40–59 y	10 371	2088	20.1 (19.4 to 20.9)
≥60 y	708	245	34.6 (31.1 to 38.2)
p-trend ^a	NA	NA	0.0333
Female	23 455	1538	6.6 (6.2 to 6.9)
≤39 y	13 687	383	2.8 (2.5 to 3.1)
40–59 y	9505	1073	11.2 (10.7 to 11.9)
≥60 y	263	82	31.2 (25.6 to 37.2)
p-trend ^a	NA	NA	0.0106
Total	42 785	4401	10.3 (10.0 to 10.6)
≤39 y	21 938	913	4.2 (3.9 to 4.4)
40–59 y	19 876	3161	15.9 (15.4 to 16.4)
≥60 y	971	327	33.7 (30.7 to 36.8)
p-trend ^a	NA	NA	0.0111

^ap for trend <0.05.
p-trend bolding: The results of p for trend were statistical significance.
NA: not available; 95% CI: 95% confidential interval.

Obesity was then defined as having a BMI greater than 25 kg/m², which was classified as ‘yes’, and a BMI less than 25 kg/m² classified as ‘no’.^{9,10} A BMI over 25 kg/m² was defined as obese according to the specific cut-off for Asian populations, rather than the general WHO definition of over 30 kg/m² as obese.¹⁰

There were 12 conditions in this study (see Table 2). Multimorbidity was defined as the same individual having two or more of these 12 chronic conditions being reported as ‘yes’. The chronic conditions included cardiometabolic conditionxs (hyperlipidaemia, hypertension, ischaemic heart disease and stroke), cancers (of liver, lung, stomach, colon-rectum and breast) and other conditions (kidney diseases and obesity). The patterns of multimorbidity were defined in this study, based on the three most prevalent clusters of chronic diseases.

Analysis

Descriptive analyses were used to explain the variables in the study, including the prevalence of multimorbidity, the proportion of participants with each chronic disease, the average number of chronic diseases among individuals, and the distribution of individuals assigned to different numbers of chronic diseases. Prevalence-based analysis was used to rank the most prevalent chronic disease combinations (the common multimorbidity patterns). A chi-square test was used to examine the relationship between gender and/or age and the prevalence of these patterns. P for trend (p-trend), was used to test whether the variable showed a significance trend in response to change in another ordered

Table 2. Number and proportion of participants with each chronic condition and the mean number of chronic diseases among individuals in the Thai Cohort Study in 2013

	Mean number of conditions													Total conditions (n)	Mean number of conditions (n ±SD)
	Diabetes (n (%))	High cholesterol/ high blood lipids (n (%))	High blood pressure (n (%))	Ischemic heart disease (n (%))	Cerebrovascular disease/stroke (n (%))	Obesity (n (%))	Liver cancer (n (%))	Lung cancer (n (%))	Stomach cancer (n (%))	Colon-rectum cancer (n (%))	Breast cancer (n (%))	Kidney disease (n (%))			
Male															
All age	691 (3.6)	3188 (16.5)	2009 (10.4)	110 (0.6)	96 (0.5)	7089 (36.7)	18 (0.1)	12 (0.1)	38 (0.2)	24 (0.1)	8 (0.0)	177 (0.9)	13460	0.70±0.02	
≤39 y	75 (0.9)	619 (7.5)	309 (3.8)	11 (0.1)	13 (0.2)	2668 (32.3)	6 (0.1)	5 (0.1)	24 (0.3)	6 (0.1)	5 (0.1)	45 (0.6)	3786	0.46±0.01	
40–59 y	527 (5.1)	2354 (22.7)	1456 (14.0)	72 (0.7)	66 (0.6)	4166 (40.2)	10 (0.1)	7 (0.1)	14 (0.1)	14 (0.1)	3 (0.0)	113 (1.1)	8802	0.85±0.01	
≥60 y	89 (12.6)	215 (30.4)	244 (34.5)	27 (3.8)	17 (2.4)	255 (36.0)	2 (0.3)	0	0	4 (0.6)	0	19 (2.7)	872	1.23±0.04	
p-trend ^a	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.0408	NS	NA	0.0441	
Female															
All age	350 (1.5)	2473 (10.5)	1059 (4.5)	25 (0.1)	65 (0.3)	5098 (21.7)	3 (0.0)	11 (0.1)	54 (0.2)	10 (0.0)	96 (0.4)	161 (0.6)	9405	0.40±0.02	
≤39 y	87 (0.6)	712 (5.2)	211 (1.5)	7 (0.1)	19 (0.1)	2527 (18.5)	3 (0.0)	6 (0.0)	43 (0.3)	5 (0.0)	17 (0.1)	86 (0.6)	3723	0.27±0.01	
40–59 y	244 (2.6)	1661 (17.5)	777 (8.2)	18 (0.2)	44 (0.5)	2472 (26.0)	0	5 (0.1)	11 (0.1)	4 (0.0)	78 (0.8)	72 (0.8)	5386	0.57±0.01	
≥60 y	19 (7.2)	100 (38.0)	71 (27.0)	0	2 (0.8)	99 (37.6)	0	0	0	1 (0.4)	1 (0.4)	3 (1.1)	296	1.13±0.05	
p-trend ^a	NS	0.0135	NS	NS	NS	0.0006	NS	NS	NS	NS	NS	NS	NA	0.0316	
Total															
All age	1041 (2.4)	5661 (13.2)	3068 (7.2)	135 (0.3)	161 (0.4)	12187 (28.5)	21 (0.1)	23 (0.1)	92 (0.2)	34 (0.1)	104 (0.2)	338 (0.8)	22865	0.53±0.01	
≤39 y	162 (0.7)	1331 (6.1)	520 (2.4)	18 (0.1)	32 (0.1)	5195 (23.7)	9 (0.0)	11 (0.1)	67 (0.3)	11 (0.1)	22 (0.1)	131 (0.6)	7509	0.34±0.01	
40–59 y	771 (3.9)	4015 (20.2)	2233 (11.2)	90 (0.5)	110 (0.6)	6638 (33.4)	10 (0.1)	12 (0.1)	25 (0.1)	18 (0.1)	81 (0.4)	185 (0.9)	14188	0.71±0.01	
≥60 y	108 (11.1)	315 (32.4)	315 (32.4)	27 (2.8)	19 (2.0)	354 (36.5)	2 (0.2)	0	0	5 (0.5)	1 (0.1)	22 (2.3)	1168	1.20±0.04	
p-trend ^a	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NA	0.0120	

^ap for trend <0.05.

p-trend bolding: The results of p for trend were statistical significance.

NA: not available; SD: standard deviation; NS: not significant.

variable. P-trend was used to measure two associations: one is between the prevalence of multiple chronic conditions and age (median age of participants with these diseases in different age groups); the other one is the distribution of number of chronic conditions and their prevalence. All statistical significance levels were defined as p-value less than 5%. Statistical analyses with drawn graphs were produced using STATA 16 with Excel 2016.

Results

A total of 42 785 participants aged 23 to 96 were included in the study, with approximately 45.2% being men and 2.3% aged 60+ (3.7% of men were over 60) (see Table 1). About 10.3% of participants had two or more chronic diseases concurrently, indicating multimorbidity, notably more prevalent in males (around 14.8% vs 6.6% in females). Additionally, there was a positive linear association between age and multimorbidity prevalence (p-trend = 0.0111) in Table 1.

In Table 2, the average number of diseases per person rose from 0.53 for all ages to 1.20 for individuals over 60, exhibiting a linear increase with age (p-trend = 0.0120). The chronic conditions with high prevalence were metabolic syndrome-related conditions. Of these, obesity was most prevalent in both genders (total: 28.5%), followed by hyperlipidaemia (total: 13.2%) and hypertension (total: 7.2%) (see Table 2). Moreover, three common multimorbidity patterns were identified: hyperlipidaemia + obesity, hypertension + obesity, and hyperlipidaemia + hypertension + obesity.

Table 3 indicated that individuals with four or more diseases were less common compared to those with one or two diseases (p-trend = 0.0330). This difference was not significant among those under 39 y but showed significance in the 40–59 y group (p-trend = 0.0168) and in the 60+ y group (p-trend = 0.0026). Among all participants, around 61.0% had no diseases, 28.7% had one condition, and around 7.2% had two diseases. Nonetheless, disease prevalence increased with age, with only about one-third of individuals aged 60 and above being disease-free.

In Table 4, the three most common patterns of multimorbidity (based on the prevalence of these chronic conditions combination) were hyperlipidaemia + obesity, hypertension + obesity, and hyperlipidaemia + hypertension + obesity. The top was hyperlipidaemia + obesity, affecting 30.4% of individuals with multimorbidity (men: 29.8%, women: 31.5%). Following this, hypertension + obesity was the second most prevalent, accounting for 16.5% overall, with 15.9% of men and 17.5% of women experiencing multimorbidity. Hyperlipidaemia + hypertension + obesity was reported in 16.0% of men, 10.6% of women, totalling 14.1% in the multimorbid population (see Table 4).

Among the three multimorbidity patterns (see Table 4), hyperlipidaemia + obesity was most prevalent in both male and female multimorbid patients under 39 y, constituting 40.2% and 36.6% (total: 38.7%), respectively. This pattern slightly decreased with age but lacked significant decline. Hypertension + obesity was less common in the over-60 age group, making up 15.6% of the multimorbid population. Hyperlipidaemia + hypertension + obesity prevailed in middle age and older multimorbid individuals,

with the highest occurrence observed among males aged 40–59 y (16.7%) and females over 60 y (19.5%).

In the over 60 age group, hypertension + obesity prevalence reached 5.4% in men and 4.9% in women, notably higher in men. Meanwhile, hyperlipidaemia + hypertension + obesity in this age group was 0.9% higher in females compared to males in Table 4. Additionally, among individuals over 60, women (6.1%) were more likely than men (3.1%) to experience hyperlipidaemia + obesity. The prevalence of hypertension + obesity increased with age for all participants, demonstrating a significant upward trend (p-trend = 0.0214). Overall, men appeared to have a higher likelihood of experiencing all three multimorbidity patterns compared to women across all participants (see Table 4).

Discussion

About one-third of participants over the age of 60 had two or more chronic conditions at the same time and nearly 70% were classified as having at least one disease in this study. Even amongst participants aged between 40 and 59 y multimorbidity prevalence was near 16.0%. About half of the population had at least one chronic condition, and one in seven suffered from two or more diseases. This suggests that multimorbidity may no longer be the ‘preserve’ of the elderly. This was also confirmed in studies in Canada and Northern Ireland that found an increasing number of younger and middle-aged people (from 25 to 60 y) were suffering from multimorbidity.^{12,13} However, such a phenomenon has not yet been shown in low- and middle-income countries, which may possibly be related to the lack of research on multimorbidity in these countries.¹⁴

In our study, young people in Thailand were more likely to suffer from multimorbidity pattern in terms of metabolic syndromes such as obesity and hyperlipidaemia, which may be related to high-oil, high-salt, and high-sugar diets, as well as sedentary lifestyle habits.¹⁵ However, the mechanism of multimorbidity in an increasing number of young and middle-aged people still needs to be elucidated by more research, and there is no clear understanding at this present time.^{1,2} Nevertheless, age is still the most important factor in multimorbidity, and the older people are, the more likely they are to develop it.¹⁶ Thus, increased susceptibility to multiple chronic conditions is also a characteristic of the ageing society.

The prevalence of multimorbidity was higher in men than in women in all age groups in this paper, contrary to the results of some other papers. In studies from Aragon and Catalonia¹⁷ and Bangladesh,¹⁸ the prevalence of multimorbidity was higher in females than in males in both older and relatively younger age groups. It has been suggested that physical multimorbidity may be more common in men and physical-mental multimorbidity more common in women, so that the different chronic conditions included in multimorbidity may also have some influence on gender-related outcomes.¹⁹

Psychiatric disorders were not included in our research, which may have had some impact on our gender-related results, which differed from other studies.^{17,18,20} However, some studies that did include psychiatric disorders, still found no significant difference in the prevalence of multimorbidity

Table 3. Distribution of number of chronic conditions in the Thai Cohort Study in 2013

	All age, proportion (%) (95% CI)	Age groups			p-trend ^a
		≤39 y, proportion (%) (95% CI)	40–59 y, proportion (%) (95% CI)	≥60 y, proportion (%) (95% CI)	
Male					
Number of conditions					
No condition	51.8 (51.1 to 52.5)	62.7 (61.6 to 63.7)	44.3 (43.3 to 45.2)	35.3 (31.8 to 38.9)	NS
One condition	33.9 (33.2 to 34.5)	30.9 (29.9 to 31.9)	35.6 (34.7 to 36.5)	30.1 (26.7 to 33.6)	NS
Two conditions	10.0 (9.6 to 10.4)	4.8 (4.4 to 5.3)	13.4 (12.8 to 14.1)	18.6 (15.8 to 21.7)	NS
Three conditions	3.8 (3.6 to 4.1)	1.4 (1.1 to 1.6)	5.3 (4.9 to 5.8)	10.5 (8.3 to 12.9)	0.0466
Four conditions	0.9 (0.8 to 1.1)	0.2 (0.1 to 0.3)	1.2 (1.0 to 1.5)	4.5 (3.1 to 6.3)	NS
More than four conditions	0.0 (0.0 to 0.2)	0.0 (0.0 to 0.1)	0.0 (0.0 to 0.3)	0.4 (0.4 to 2.0)	NS
p-trend ^a	0.0182	0.0395	0.0115	0.0021	NA
Female					
Number of conditions					
No condition	68.6 (68.0 to 69.2)	76.2 (75.5 to 76.9)	58.8 (57.8 to 59.8)	29.7 (24.2 to 35.6)	0.0139
One condition	24.8 (24.3 to 25.4)	21.0 (20.3 to 21.7)	29.9 (29.0 to 30.8)	39.7 (33.2 to 45.4)	NS
Two conditions	4.9 (4.6 to 5.2)	2.3 (2.1 to 2.6)	8.1 (7.5 to 8.7)	21.3 (16.5 to 26.7)	NS
Three conditions	1.3 (1.1 to 1.4)	0.4 (0.3 to 0.5)	2.4 (2.1 to 2.7)	8.8 (5.6 to 12.8)	NS
Four conditions	0.4 (0.3 to 0.5)	0.1 (0.1 to 0.2)	0.8 (0.7 to 1.0)	1.14 (0.2 to 3.3)	NS
More than four conditions	0.0 (0.0 to 0.1)	0.0 (0.0 to 0.1)	0.0 (0.0 to 0.1)	0	NS
p-trend ^a	0.0512	.0739	0.0294	0.0062	NA
Total					
Number of conditions					
No condition	61.0 (60.6 to 61.5)	71.1 (70.5 to 71.7)	51.2 (50.5 to 51.9)	33.7 (36.2 to 42.4)	NS
One condition	28.7 (28.3 to 29.1)	24.7 (24.2 to 25.3)	32.9 (32.2 to 33.5)	32.5 (29.6 to 35.6)	NS
Two conditions	7.16 (6.9 to 7.4)	3.3 (3.0 to 3.5)	10.9 (10.4 to 11.3)	19.3 (16.8 to 21.9)	0.0182
Three conditions	2.4 (2.3 to 2.6)	0.7 (0.6 to 0.9)	3.9 (3.6 to 4.2)	10.0 (8.1 to 12.1)	NS
Four conditions	0.6 (0.6 to 0.7)	0.1 (0.1 to 0.2)	1.0 (0.9 to 1.2)	3.6 (2.5 to 5.0)	0.0320
More than four conditions	0.1 (0.1 to 0.1)	0.0 (0.0 to 0.1)	0.1 (0.1 to 0.12)	0.7 (0.3 to 1.5)	NS
p-trend ^a	0.0330	0.0575	0.0168	0.0026	NA

^ap for trend <0.05.**p-trend bolding:** The results of p for trend were statistical significance.

NA: not available; 95% CI: 95% confidential interval; NS: not significant.

between men and women.²¹ It is also necessary to mention that in the TCS, the study population were more educated than the general population. In particular, the higher educational attainment of the women in the TCS may have caused some differences with Thai women as a whole.^{3,9} Thus, we could not determine which of these factors should play a dominant role.^{19–21} Gender may have an impact on multimorbidity and its patterns, but there are fewer articles addressing these aspects, particularly gender-related patterns of multimorbidity.¹⁷

The vast majority of patients with multimorbidity had two to three diseases in our study, which is similar to a study in Indonesia.²² Furthermore, the findings from studies in Indonesia,²² Thailand and the Philippines²³ showed that metabolic syndromes including obesity, hypertension and hy-

perlipidaemia were among the most prevalent chronic conditions. And several of the most common combinations of chronic diseases in these studies were also related to obesity, hypertension and hyperlipidaemia.^{22,23} However, it is worth noting that most prevalent disease in our study was obesity, with one in three to four people being obese, which was similar to the national prevalence of obesity (BMI over 25 kg/m²) in Thailand.^{24–26}

Prevalence increased with age for all three multimorbidity patterns in this research, which is also consistent with previous studies in Asia.^{21–23} One of the possible reasons is that obesity, hyperlipidaemia and hypertension are also chronic diseases whose prevalence would increase progressively with age.²⁷ In addition, in the Yi et al. study,²⁸ the prevalence of metabolic syndrome (including obesity, hyperlipidaemia and hypertension) was higher

Table 4. Prevalence of the three most frequent multimorbidity patterns (hyperlipidemia + obesity, hypertension + obesity, and hyperlipidemia + hypertension + obesity) among individuals in the Thai Cohort Study in 2013

Age groups	Number of patients (n)	Proportion among all participants (%) (95% CI)	Proportion (%) of patients among multimorbid population (95% CI)
Hyperlipidemia + obesity			
Male			
All ages	854	4.4 (4.1 to 4.7)	29.8 (28.2 to 31.5)
≤39 y	213	2.6 (2.3 to 3.0)	40.2 (36.0 to 44.5)
40–59 y	619	6.0 (5.5 to 6.4)	29.7 (27.7 to 31.7)
≥60 y	22	3.1 (2.0 to 4.7)	9.0 (5.7 to 13.3)
p-trend ^a	NA	NS	0.0396
Female			
All ages	484	2.1 (1.9 to 2.2)	31.5 (29.2 to 33.9)
≤39 y	140	1.0 (0.9 to 1.2)	36.6 (31.7 to 41.6)
40–59 y	328	3.5 (3.1 to 3.8)	30.6 (27.8 to 33.4)
≥60 y	16	6.1 (3.5 to 9.7)	19.5 (11.6 to 29.7)
p-trend ^a	NA	NS	0.0301
Total			
All ages	1338	3.1 (3.0 to 3.3)	30.4 (29.1 to 31.8)
≤39 y	353	1.6 (1.5 to 1.8)	38.7 (35.5 to 41.9)
40–59 y	947	4.8 (4.5 to 5.1)	30.0 (28.4 to 31.6)
≥60 y	38	3.9 (2.8 to 5.3)	11.6 (8.4 to 15.6)
p-trend ^a	NA	NS	0.0411
Hypertension + obesity			
Male			
All ages	455	2.4 (2.1 to 2.6)	15.9 (14.6 to 17.3)
≤39 y	102	1.2 (1.0 to 1.5)	19.3 (16.0 to 22.9)
40–59 y	315	3.0 (2.7 to 3.4)	15.1 (13.6 to 16.7)
≥60 y	38	5.4 (3.8 to 7.3)	15.5 (11.2 to 20.7)
p-trend ^a	NA	0.0313	NS
Female			
All ages	269	1.2 (1.0 to 1.3)	17.5 (15.6 to 19.5)
≤39 y	73	0.5 (0.4 to 0.7)	19.1 (15.3 to 23.4)
40–59 y	183	1.9 (1.7 to 2.2)	17.1 (14.9 to 19.4)
≥60 y	13	4.9 (2.7 to 8.3)	15.9 (8.7 to 25.6)
p-trend ^a	NA	NS	NS
Total			
All ages	724	1.7 (1.6 to 1.8)	16.5 (15.4 to 17.6)
≤39 y	175	0.8 (0.7 to 0.9)	19.2 (16.7 to 21.9)
40–59 y	498	2.5 (2.3 to 2.7)	15.8 (14.5 to 17.1)
≥60 y	51	5.3 (3.9 to 6.9)	15.6 (11.8 to 20.0)
p-trend ^a	NA	0.0214	NS
Hyperlipidemia + hypertension + obesity			
Male			
All ages	457	2.4 (2.2 to 2.6)	16.0 (14.6 to 17.4)
≤39 y	72	0.9 (0.7 to 1.1)	13.6 (10.8 to 16.8)
40–59 y	348	3.4 (3.0 to 3.7)	16.7 (15.1 to 18.3)
≥60 y	37	5.2 (3.7 to 7.1)	15.1 (10.9 to 20.2)
p-trend ^a	NA	NS	NS
Female			
All ages	163	0.7 (0.6 to 0.8)	10.6 (9.1 to 12.2)
≤39 y	19	0.1 (0.1 to 0.2)	5.0 (3.0 to 7.6)
40–59 y	128	1.4 (1.1 to 1.6)	11.9 (10.1 to 14.0)
≥60 y	16	6.1 (3.5 to 9.7)	19.5 (11.6 to 29.7)
p-trend ^a	NA	NS	NS

Table 4. (Continued)

Age groups	Number of patients (n)	Proportion among all participants (%) (95% CI)	Proportion (%) of patients among multimorbid population (95% CI)
Total			
All ages	620	1.5 (1.3 to 1.6)	14.1 (13.1 to 15.2)
≤39 y	91	0.4 (0.3 to 0.5)	10.0 (8.1 to 12.1)
40–59 y	476	2.4 (2.2 to 2.6)	15.1 (13.8 to 16.4)
≥60 y	53	5.5 (4.1 to 7.1)	16.2 (12.4 to 20.7)
p-trend ^a	NA	0.0158	NS

^ap for trend <0.05.
p-trend bolding: The results of p for trend were statistical significance.
NA: not available; 95% CI: 95% confidential interval; NS: not significant.

in men compared to all-age female participants. Nevertheless, the prevalence was higher in older women (over 60 y) than in men, whereas in the under 60 age group, the prevalence was higher in men than in women, which was also similar to our findings. The results in our study showed that the prevalence of the three most common multimorbidity patterns was higher in males than females, while in the patterns of multimorbidity of hyperlipidaemia + hypertension + obesity and hyperlipidaemia + obesity, the prevalence was higher in women than in men in the 60+ y age group.

Strengths and limitations

This article was the first attempt to use age and gender stratification to explore the prevalence of multimorbidity and the patterns of multimorbidity that were common in the TCS. Although the method of data collection for diseases in this study was self-report, potentially producing recall bias, the research by Papier et al.¹¹ revealed a high degree of concordance between the self-reported collected disease data in the TCS and the clinical assessments, which further supported the reliability and accuracy of our self-reported data.^{9,11} In this study, obesity was included as a chronic condition because obesity is considered an entry point for multimorbidity, and the inclusion of obesity as a pathological condition rather than a risk factor in the study of multimorbidity could provide an evidence base for the prevention and treatment of obesity-related multimorbidity.^{22,29,30}

However, this article also had some shortcomings. First, this paper was a cross-sectional study, so it would be not possible to determine the causal relationship between age, gender and multimorbidity.^{29,30} The data of the study was collected in 2013, about a decade ago, thus multimorbidity patterns may change over the years. In addition, the other limitation was that there was a lack of information on mental illness as well as on the severity of chronic conditions in the TCS.¹⁹ Since the members in the study were open university students, their age distribution was generally younger and they were better educated than the Thai population in general.^{9,10}

Future research

It is imperative to take into account gender and age differences in future studies of multimorbidity and its patterns, especially those in which multimorbidity is associated with the metabolic syndrome. Conducting longitudinal studies is also essential to explore the causal relationship between gender, age and multimorbidity, along with different patterns of multimorbidity in Thailand.^{1,2} These studies can provide local governments with detailed information that can help them to develop more effective multimorbidity prevention and treatment programmes for people of different genders and ages, to achieve better preventive and therapeutic outcomes.^{1,2}

Conclusion

Metabolic syndrome-related factors were the most prevalent chronic conditions among multimorbidity. In addition, there were significant age and gender differences in the prevalence of multimorbidity and the most common of patterns of multimorbidity. People aged over 60 y were at highest risk for multimorbidity, while younger individuals under the age of 40 y tended to have the multimorbidity pattern of obesity and hyperlipidaemia. Moreover, in comparison to women, men showed a higher likelihood of multimorbidity, and multimorbidity patterns associated with metabolic syndrome (including obesity, hypertension and hyperlipidaemia) were also more prevalent among males. Therefore, it is necessary to consider gender and age differences in future studies of multimorbidity and its patterns, especially those addressing metabolic syndromes in Thailand. Research on multimorbidity should be stratified by sex and age to ensure a more comprehensive understanding of the situation in different population groups.

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the manuscript for intellectual content. All authors read and approved the final manuscript. XF and MK are the guarantors of the paper.

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Chapter 6 The health-risk factors of multimorbidity in Thailand

The previous chapter examined the prevalence and patterns of multimorbidity in Thailand by age and sex, using data from the Thai Cohort Study (TCS). That analysis established important baseline evidence, showing that multimorbidity was more common among older adults and males. However, the focus on age and sex also highlighted limitations, as it did not capture the broader range of social and behavioural determinants that may contribute to multimorbidity.

Building on these findings, this chapter aims to move beyond demographic characteristics and identify additional risk factors associated with multimorbidity in Thailand. In particular, we incorporate behavioural and lifestyle risk factors such as smoking, alcohol consumption, physical activity, and body mass index, alongside socioeconomic measures, in order to provide a more comprehensive understanding of the determinants of multimorbidity.

In addition, this chapter employs spatial analysis to examine geographic variation in multimorbidity across Thailand. While based on historical cohort data, such analysis remains valuable for identifying past hotspots and patterns of disease clustering, which can inform resource allocation and policy priorities. Mapping these patterns provides insights into regional disparities, helps to contextualize emerging trends, and highlights areas where preventive strategies and healthcare infrastructure may need to be strengthened.

The objective of this chapter, therefore, is to provide evidence on the combined influence of social, behavioural, and geographic factors on multimorbidity in Thailand. By identifying at-risk populations and regions, the findings can guide targeted prevention strategies and contribute to the development of effective public health policies aimed at reducing the burden of multimorbidity.

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

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Association of socio-demographic and lifestyle factors with multimorbidity among adults in the Thai Cohort Study

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Abstract

Aim The aim of this study was to examine the relationship between socio-demographic and lifestyle factors and multimorbidity among Thai adults.

Subject and methods This cross-sectional study used data from 42,785 members of the Thai Cohort Study (TCS) in 2013 to identify risk factors associated with the prevalence of multimorbidity (coexistence of two or more chronic conditions). Multivariate logistic regression was applied to examine the correlation between socio-demographic and lifestyle elements and the prevalence of multimorbidity.

Results The overall prevalence of multimorbidity was 10.3%. The highest prevalence was found in the capital, Bangkok, at 12.9%. The older the participant, the more likely they were to suffer from multimorbidity (p -trend = 0.0452). Moreover, participants who consumed more instant food (p -trend = 0.0446) and fast food (p -trend = 0.0313) were more likely to have multimorbidity. However, the more they exercised weekly, especially doing housework, the lower the odds of having multimorbidity (p -trend = 0.0034). Occasional or social drinking also reduced the odds of having multimorbidity compared to non-drinkers (adjusted odds ratio [AOR] = 0.80; 95% CI 0.70–0.95). Notably, excessive sleep (more than 8 h, AOR = 1.29, 95% CI 1.07–1.55) or insufficient sleep (less than 6 h, AOR = 1.24, 95% CI 1.09–1.41) may increase the odds of having multimorbidity.

Conclusion The findings suggest that more attention should be paid to multimorbidity in the elderly. In addition, encouraging people to live a healthy life and engage in more exercise, such as household exercise, could be effective in reducing the likelihood of multimorbidity.

Keywords Chronic conditions · Health behaviours · Multimorbidity · Socio-demographic factors · Thai Cohort Study

Introduction

Multimorbidity, having two or more chronic health problems in the same person at the same time, is a health challenge that increases with age. Multimorbidity is also becoming a global public health problem in light of the onset of global ageing (Willadsen et al. 2016). Due to the complexity of symptoms and higher mortality rates, the treatment requirements

for multimorbidity are more complex than those for single health conditions (Willadsen et al. 2016). Moreover, low- and middle-income countries (LMICs) are now becoming ageing societies and joining already aged high-income settings. However, the health care system is lagging in responding to the prevention and treatment of multimorbidity, thus leading to a more pronounced burden of multimorbidity in LMICs and posing a significant challenge to local health care systems (Feng et al. 2021).

Many factors contribute to the occurrence of multimorbidity. Age is the greatest factor and is positively associated with incidence (Abebe et al. 2020). In addition, the development of multimorbidity has been associated with socio-economic inequalities. Inequalities in socio-economic status (SES), including educational attainment and income level, are also associated with risk of multimorbidity (Abebe et al. 2020; Hosseinpoor et al. 2012). This

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is because people with low SES usually have less education and health knowledge and are also challenged by the social determinants of a healthy lifestyle (Hosseinpoor et al. 2012). For example, these individuals may not be able to afford healthy food or exercise programmes, which makes them more vulnerable to the development of multimorbidity (Hosseinpoor et al. 2012). In addition, when multimorbidity occurs, these individuals often do not have adequate access to medical resources to manage it due to the burden of costly treatment (Hosseinpoor et al. 2012).

Most of Southeast Asia is made up of LMICs, and inequality in SES is also evident (Feng et al. 2021). It has been shown that in countries such as Vietnam and Indonesia, the prevalence of multimorbidity is high among people with low socio-economic conditions, including low income, low education, and unemployment (Ha et al. 2015; Mahwati 2014). In addition to age and SES, some lifestyle habits are also related to multimorbidity. For instance, smoking was found to increase the incidence of multimorbidity among Malaysians (Hussin et al. 2019). Moreover, Indonesian scholars have demonstrated that sedentary lifestyles are also associated with multimorbidity (Mahwati 2014).

Thailand is one of the LMICs located in Southeast Asia. With the health transition brought about by the growing economy and society, the incidence of multimorbidity, mainly non-communicable diseases (NCDs), has become a major health threat to the Thai population (Intarut et al. 2021). However, similar to other developing regions, Thailand is still focused on single-disease studies, and research on multimorbidity is in the preliminary stage (Feng et al. 2021; Intarut et al. 2021). We analyse data from a large cohort study in Thailand to identify locally relevant risk factors for multimorbidity (Sleigh et al. 2008). This study not only may provide valuable insights into the life course health risks of Thais but also may provide favourable information for studying risk factors associated with multimorbidity (Feng et al. 2021; Intarut et al. 2021; Sleight et al. 2008).

The study reported herein is firstly involved in the association of risk factors with the prevalence of multimorbidity in the Thai Cohort Study (TCS) in 2013. Our findings will inform the prevention of multimorbidity to identify the Thai population most at risk.

Methods

The study population

The TCS is a nationwide project to investigate the country's ongoing health risk transition (shift in disease burden from communicable diseases to NCDs). The project began in 2005 and has recruited 87,134 people who enrolled at Sukhothai Thammathirat Open University (STOU) in Thailand.

Participants in this study came from across the country and were aged from 15 to 87 years at baseline. These respondents were reasonably representative of STOU's student population and the general Thai population, as their median age, median income, region, and ethnic diversity were similar to the national demographic (Sleigh et al. 2008). However, they had a lower mean age and were better educated than adults across Thailand. Moreover, a higher proportion of STOU students live in urban areas (Sleigh et al. 2008).

Data collection

Data were collected from three mailed questionnaires. The first one was in 2005 (baseline), with follow-up surveys in 2009 and 2013. In each round of follow-up, approximately 70% of the cohort members were retained in the study. The three questionnaires included basic demographic information such as age, gender, and home address, as well as work and income, living and working environment, and personal and family history of illness, personal lifestyle (e.g. diet and exercise), and other relevant information including injuries and transportation. This is a cross-sectional study, based on a 2013 mailed questionnaire with 42,785 respondents in TCS (Feng et al. 2020; Sleight et al. 2008).

The definition of multimorbidity

In this study, multimorbidity was defined as suffering from two or more chronic diseases at the same time. This is the most common definition of multimorbidity used in epidemiological studies (Willadsen et al. 2016).

In the 2013 follow-up survey, one of the questions was whether the respondent had been diagnosed by a physician with any of the 11 diseases listed, with “yes” reported for those with these diseases and “no” reported for those without these diseases (Feng et al. 2020). The 11 diseases are diabetes, high cholesterol, hypertension, ischemic (coronary) heart disease, stroke, kidney disease, liver cancer, lung cancer, stomach cancer, colon cancer, and breast cancer. Participants also reported their height and weight. We additionally calculated participants' body mass index (BMI) and classified those with a BMI greater than 25 as obese (Banks et al. 2011; Sleight et al. 2008). Therefore, multimorbidity was defined as two or more of these 12 diseases (including obesity) being reported as “yes” for the same individual (see Table 1).

Health risk factors (socio-demographic and lifestyle factors)

A variety of health risk factors for multimorbidity were also identified in this study by referring to other studies on multimorbidity (Hosseinpoor et al. 2012; Willadsen et al.

Table 1 Chronic conditions and three patterns of multimorbidity in the Thai Cohort Study (TCS) in 2013

Chronic conditions		
Metabolic disorders	Cardiometabolic conditions	Diabetes
		High cholesterol
		Hypertension
		Ischemic (coronary) heart disease
		Stroke
		Kidney disease
		Obesity
Cancers		Liver cancer
		Lung cancer
		Stomach cancer
		Colorectal cancer
		Breast cancer

2016), combined with the TCS questionnaire. The risk factors associated with multimorbidity can be broadly classified into two major categories: socio-demographic factors and healthy behaviour/personal lifestyle factors (see Table 2).

Statistical analysis

All analyses were computed by Stata 16.0. The prevalence of multimorbidity and its 95% confidential interval (CI) were calculated separately for men and women respondents. Differences between the prevalence for risk factor groups were assessed by the χ^2 test. P for trend (p-trend) was used to test the linear trend. All statistical significance was defined as a *p*-value less than 5%.

Logistic regression was used to analyse the association between health risk factors and the prevalence of multimorbidity. A stratified analysis was performed for gender. Multivariate logistic regression models were used to assess multivariate AORs between risk factors and multimorbidity. For each set of associations, we adjusted for different confounders based on our descriptive data and observations from the rest of the literature. For details, see Table 2.

Results

Characteristics of the participants in the Thai Cohort Study (TCS)

The TCS included 42,785 participants. Table 3 shows the characteristics of the 2013 TCS. There were more female participants than males (54.8% vs 45.2%). The largest proportion of males was in the 40–59 age group (53.7%), while the

largest proportion of females was in the under 39 age group (58.4%). Furthermore, more people were living with their partner (64.0%) than were single. The highest proportion of people lived in central Thailand (22.6%) and moved from an urban area when they were children to a rural area when they got older (34.6%). The educational level of women (81.8% at university level) was higher than that of men (77.3%). In addition, in terms of personal salary, about 40.4% of the people earned more than 20,000 baht per month. As for the household income, 69.2% of participants lived in households with income exceeding 20,000 baht per month.

Socio-demographic and lifestyle factors, and multimorbidity

The prevalence of multimorbidity among all participants was 10.3%, the proportion of males was 14.8%, and the percentage of females was 6.6% (see Table 4). The prevalence of multimorbidity increased with age in men (p-trend = 0.0333), women (p-trend = 0.0106), and the total participants (p-trend = 0.0111). The highest prevalence of people with multimorbidity lived in Bangkok, the capital city, with 18.6% for men, 9.2% for women, and 12.9% for the total. Those who had grown up in urban areas and then moved to a rural area (urban–rural, UR) had the highest prevalence of multimorbidity at 13.6%. The lowest prevalence of multimorbidity, at 9.2%, was found in the urbanizing group (rural–urban, RU) who had been in the countryside as a child and moved to the city when they were older (see Table 4).

The prevalence of multimorbidity was higher among those who never ate instant food (male = 17.4%; female = 8.5%; total = 12.4%). However, about 13.2% of people who ate fast food daily had developed multimorbidity (see Table 4).

The more housework that participants did, the lower the prevalence of multimorbidity (total p-trend = 0.0269). As for sleep time, morbidity was more prevalent in those with less than or equal to 6 h (10.3%) or greater than or equal to 13 h (11.0%), and the prevalence of multimorbidity was higher when the sedentary time was 8–12 h (10.1%) (see Table 4).

The prevalence of multimorbidity among non-current smokers was around 5% lower than among current smokers (see Table 4). Moreover, the prevalence of multimorbidity was also highest in those who drank alcohol regularly (current regular vs never: 16.7% vs 8.6%) (see Table 4).

After controlling for the other factors, female participants had a lower likelihood of multimorbidity than male participants (AOR = 0.46, 95% CI 0.39–0.53). The older the participants were, the more likely they were to have multimorbidity (male: p-trend = 0.0475; female: p-trend = 0.0141; total: p-trend = 0.0452) after adjusting for other variables. Participants living in the southern part of Thailand (AOR = 0.74, 95% CI 0.59–0.92) appeared

Table 2 Risk factors for multimorbidity in the Thai Cohort Study (TCS)

Domain	Variables	Confounders
Socio-demographic factors	Gender: male (reference) or female	Age, marital status, geographic regions, life course residence, monthly personal income, monthly household income, educational levels
	Age (years): ≤ 39 (reference), 40–59, or ≥ 60	All factors of health behaviours Gender, marital status, geographic regions, life course residence, monthly personal income, monthly household income, educational levels
	Marital status: living with partner (reference) or single	All factors of health behaviours Gender, age, geographic regions, life course residence, monthly personal income, monthly household income, educational levels
	Geographic regions: Bangkok (reference), Central, North, Northeast, East, or South	All factors of health behaviours Gender, age, marital status, life course residence, monthly personal income, monthly household income, educational levels
	Life course residence*: rural–rural (lifelong ruralites, RR) (reference), rural–urban (urbanizers, RU), urban–rural (de-urbanizers, UR), or urban–urban (urbanites, UU)	All factors of health behaviours Gender, age, marital status, geographic regions, monthly personal income, monthly household income, educational levels
	Monthly personal income (baht): ≤ 7000 (reference), 7001–10,000, 10,001–20,000, or $\geq 20,001$ (One US dollar was equivalent to around 35 baht in 2013)	All factors of health behaviours Gender, age, marital status, geographic regions, life course residence, monthly household income, educational levels
	Monthly household income (baht): $\leq 7,000$ (reference), 7001–10,000, 10,001–20,000, or $\geq 20,001$ (One US dollar was equivalent to around 35 baht in 2013)	All factors of health behaviours Gender, age, marital status, geographic regions, life course residence, monthly personal income, educational levels
	Educational levels: junior school (reference), high school, diploma, or university	All factors of health behaviours Gender, age, marital status, geographic regions, life course residence, personal monthly income, monthly household income
		All factors of health behaviours

Table 2 (continued)

Domain	Variables	Confounders
Health behaviours/personal lifestyles	Dietary consumption	Deep-fried food, instant food, soft drinks, fast food: less than once a month (reference), 1–3 times a month, 1–2 times a week, 3–6 times a week, or daily or more
		All socio-demographic factors, fruits, vegetables, sugar, weekly exercise, housework, sleep time, sedentary time, smoking status, drinking status
		Fruits, vegetables, sugar (servings/day) ^{**} : 0–4 (reference), 5–9, 10–14, or ≥ 15
Activity status		All socio-demographic factors, deep-fried food, instant food, soft drinks, fast food, fruits, vegetables, sugar, smoking status, drinking status
		Weekly exercise [#] : 0–7 (reference), 8–14, or ≥ 15 ; housework (indoor chores: household cleaning and outdoor tasks; gardening work): 1–3 times a month (reference), 1–2 times a week, 3–4 times a week, or every day or more; sleep time (hours/day): ≤ 6 h, 7–8 h (reference), or ≥ 9 h; sedentary time (hours/day): ≤ 7 h (reference), 8–12 h, or ≥ 13 h
Smoking and drinking status		All socio-demographic factors, deep-fried food, instant food, soft drinks, fast food, fruits, vegetables, sugar, weekly exercise, housework, sleep time, sedentary time
		Smoking status: non-current smoker (reference) or current smoker; drinking status: never (reference), ex-drinker, occasional social, or current regular

* Life course residence: life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years and again in 2005, creating four groups: lifelong ruralities (rural–rural, RR), urbanizers (rural–urban, RU), de-urbanizers (urban–rural, UR), and urbanites (urban–urban, UU) (Banks et al. 2011; Feng et al. 2020; Thawornchaisit et al. 2015; Zhao et al. 2015)

** Fruits, vegetables, sugar (servings/day): the grouping of intake of fruits, vegetables, and sugar is consistent with that of previous articles (Banks et al. 2011; Feng et al. 2020; Thawornchaisit et al. 2015; Zhao et al. 2015)

Weekly exercise: includes three groups, namely vigorous exercise over 20 min, moderate exercise over 20 min, and walking for at least 10 min. According to the International Physical Activity Questionnaire and the Australian Active Survey (Banks et al. 2011; Thawornchaisit et al. 2015; Zhao et al. 2015), this study used the adjusted exercise weights to assess weekly physical activity: 2 × vigorous exercise + 1 × moderate exercise + 1 × number of walks per week. The weekly exercise was divided into three groups, i.e. 0–7, 8–14, and ≥ 15 , which was consistent with the grouping of previous articles (Banks et al. 2011; Feng et al. 2020; Thawornchaisit et al. 2015; Zhao et al. 2015)

Table 3 The socio-demographic characteristics of participants in the 2013 Thai Cohort Study (TCS)

Factors	Male		Female		Difference <i>p</i> -value	Total	
Participants	No.	Percentage (%)	No.	Percentage (%)		No.	Percentage (%)
Age (years), mean (SD)	19,330	45.2	23,455	54.8	$p < 0.001$	42,785	100.0
Age groups (years)	42.3 (8.9)		39.0 (7.8)			40.50 (8.5)	
≤ 39	8251	42.7	13,687	58.4	$p < 0.001$	21,938	51.3
40–59	10,371	53.7	9505	40.5		19,876	46.5
≥ 60	708	3.7	263	1.1		971	2.3
Marital status							
Living with partner	13,668	71.9	13,319	57.5	$p < 0.001$	26,987	64.0
Single	5335	28.1	9832	42.5		15,167	36.0
Geographic regions							
Bangkok	2612	13.5	4130	17.6	$p < 0.001$	6742	15.8
Central	4066	21.0	5618	24.0		9684	22.6
North	4134	21.4	4458	19.0		8592	20.1
Northeast	4714	24.4	4251	18.1		8965	21.0
East	1512	7.8	1919	8.2		3431	8.0
South	2292	11.9	3079	13.1		5371	12.6
Life course residence*							
Rural–rural (RR)	1214	20.6	1217	17.4	$p < 0.001$	2641	18.9
Rural–urban (RU)	1921	27.8	2050	27.3		3971	28.6
Urban–rural (UR)	2320	33.6	2487	35.5		4807	34.6
Urban–urban (UU)	1244	18.0	1245	17.8		2489	17.9
Socio-economic status							
Education level					$p < 0.001$		
Junior school	252	1.0	120	0.5		372	0.9
High school	2875	15.0	2561	11.0		5436	12.8
Diploma	1237	6.4	1577	6.8		2814	6.6
University	14,855	77.3	19,085	81.8		33,940	79.7
Personal monthly income (baht)							
≤ 7000	1688	8.8	2392	10.3	$p < 0.001$	4080	9.6
7001–10,000	1860	9.7	3460	14.9		5320	12.6
10,001–20,000	6366	33.3	9468	40.8		15,834	37.4
≥ 20,001	9217	48.2	7870	33.9		17,087	40.4
Household assets level (baht)							
≤ 7000	1327	7.0	1281	5.5	$p < 0.001$	2608	6.2
7001–10,000	1143	6.0	1527	6.6		2670	6.3
10,001–20,000	3080	16.1	4668	20.1		7748	18.3
≥ 20,001	13,529	70.9	15,742	67.8		29,271	69.2

* Life course residence: urbanization status was categorized in terms of rural (R) or urban (U) residential residence when aged 10–12 years and again in 2005, creating four groups: lifelong ruralites (rural–rural, RR), urbanizers (rural–urban, RU), de-urbanizers (urban–rural, UR), and urbanites (urban–urban, UU) (Banks et al. 2011; Feng et al. 2020; Thawornchaisit et al. 2015; Zhao et al. 2015)

Table 4 The prevalence of multimorbidity among the participants in the Thai Cohort Study (TCS) in 2013

Participants	Male			Female			Total		
	n (%)	(95% CI)	p-value	n (%)	(95% CI)	p-value	n (%)	(95% CI)	p-value
Socio-demographic factors									
Gender	2863 (14.8)	(14.3, 15.3)		1538 (6.6)	(6.2, 6.9)	$p < 0.0001$	4401 (10.3)	(10.0, 10.6)	
Age (years)									
≤ 39	530 (6.6)	(5.9, 7.0)		383 (2.8)	(2.5, 3.1)		913 (4.2)	(3.9, 4.4)	
40–59	2088 (20.1)	(19.4, 20.9)		1073 (11.3)	(10.7, 11.9)		3161 (15.9)	(15.4, 16.4)	
≥ 60	245 (34.6)	(31.2, 38.2)		82 (31.2)	(25.9, 37.0)		327 (33.7)	(30.8, 36.7)	
<i>p</i> -trend	0.0333		$p < 0.0001$	0.0106		$p < 0.0001$	0.0111		$p < 0.0001$
Marital status									
Living with others	2251 (16.4)	(15.9, 17.1)		884 (6.6)	(6.2, 7.1)		3135 (11.6)	(11.2, 12.0)	
Single	513 (10.7)	(9.9, 11.6)	$p < 0.0001$	640 (6.5)	(6.0, 7.0)	$p = 0.698$	1213 (8.0)	(7.6, 8.4)	$p < 0.0001$
Geographic regions									
Bangkok	487 (18.6)	(17.2, 20.2)		380 (9.2)	(8.4, 10.1)		867 (12.9)	(12.1, 13.7)	
Central	659 (16.2)	(15.1, 17.4)		416 (7.4)	(6.8, 8.1)		1075 (11.1)	(10.5, 11.7)	
North	564 (13.6)	(12.6, 14.7)		257 (5.8)	(5.1, 6.5)		821 (9.6)	(9.0, 10.2)	
Northeast	671 (14.2)	(13.2, 15.3)		235 (5.5)	(4.9, 6.3)		906 (10.1)	(9.5, 10.8)	
East	207 (13.7)	(12.1, 15.5)		93 (4.9)	(4.0, 5.9)		300 (8.7)	(7.8, 9.7)	
South	275 (12.0)	(10.7, 13.4)	$p < 0.0001$	157 (5.1)	(4.4, 5.9)	$p < 0.0001$	432 (8.0)	(7.4, 8.8)	$p < 0.0001$
Life course residence*									
Rural–rural (RR)	209 (14.7)	(12.9, 16.6)		66 (5.4)	(4.3, 6.8)		275 (10.4)	(9.3, 11.6)	
Rural–urban (RU)	249 (13.0)	(11.5, 14.5)		115 (5.6)	(4.7, 6.7)		364 (9.2)	(8.3, 10.1)	
Urban–rural (UR)	429 (18.5)	(17.0, 20.1)		224 (9.0)	(7.9, 10.2)		653 (13.6)	(12.6, 14.6)	
Urban–urban (UU)	228 (18.3)	(16.3, 20.6)		95 (7.6)	(6.3, 9.2)		323 (13.0)	(11.7, 14.4)	
<i>p</i> -trend			$p < 0.0001$			$p < 0.0001$			$p < 0.0001$
Monthly personal income (baht)									
≤ 7000	203 (12.0)	(10.6, 13.7)		140 (5.9)	(5.0, 6.9)		343 (8.4)	(7.6, 9.3)	
7001–10000	162 (8.7)	(7.5, 10.1)		145 (4.2)	(3.6, 4.9)		307 (5.8)	(5.2, 6.4)	
10001–20000	662 (10.4)	(9.7, 11.2)		458 (4.8)	(4.4, 5.3)		1120 (7.1)	(6.7, 7.5)	
≥ 20001	1805 (19.6)	(18.8, 20.4)		777 (9.9)	(9.2, 10.6)		2582 (15.1)	(14.6, 15.7)	

Table 4 (continued)

Participants	Male			Female			Total		
	<i>n</i> (%)	(95% CI)	<i>p</i> -value	<i>n</i> (%)	(95% CI)	<i>p</i> -value	<i>n</i> (%)	(95% CI)	<i>p</i> -value
	<i>p</i> < 0.001			<i>p</i> < 0.001			<i>p</i> < 0.001		
<i>p</i> -trend	0.2238			0.2312			0.2147		
Monthly home income (baht)									
≤ 7000	159 (12.0)	(10.3, 13.8)		66 (5.2)	(4.1, 6.5)		225 (8.6)	(7.6, 9.8)	
7001–10000	122 (10.7)	(9.0, 12.6)		64 (4.2)	(3.3, 5.3)		186 (7.0)	(6.1, 8.0)	
10001–20000	322 (10.5)	(9.4, 12.0)		232 (5.0)	(4.4, 5.6)		554 (7.1)	(6.6, 7.8)	
≥ 20001	2225 (16.5)	(15.8, 17.1)		1158 (7.4)	(7.0, 7.8)		3383 (11.6)	(11.2, 11.9)	
<i>p</i> -trend	0.2548		<i>p</i> < 0.001	0.1897		<i>p</i> < 0.001	0.3134		<i>p</i> < 0.001
Educational level									
Junior school	42 (16.8)	(12.6, 21.8)		10 (8.3)	(4.5, 14.8)		52 (14.0)	(10.8, 17.9)	
High school	367 (12.8)	(11.6, 14.0)		171 (6.7)	(5.8, 7.7)		538 (9.9)	(9.1, 10.7)	
Diploma	263 (13.2)	(11.4, 15.2)		126 (8.0)	(6.8, 9.4)		289 (10.3)	(9.2, 11.5)	
University	2284 (15.4)	(14.8, 16.0)		1228 (6.4)	(6.1, 6.8)		3512 (10.4)	(10.0, 10.7)	
<i>p</i> -trend	0.5955		<i>p</i> = 0.001	0.3258		<i>p</i> = 0.094	0.2254		<i>p</i> = 0.091
Health behaviours/Personal lifestyles									
Diet consumptions									
Deep fried food									
Never	79 (16.6)	(13.6, 20.3)		51 (7.5)	(5.7, 9.7)		130 (11.2)	(9.5, 13.2)	
1–3 times/month	527 (15.9)	(14.7, 17.2)		288 (6.6)	(5.9, 7.3)		805 (10.5)	(9.9, 11.2)	
1–2 times/week	909 (14.0)	(13.2, 14.9)		520 (6.4)	(5.8, 6.9)		1429 (9.7)	(9.3, 10.2)	
3–6 times/week	1002 (14.6)	(13.8, 15.5)		487 (6.6)	(6.0, 7.1)		1489 (10.4)	(9.9, 10.9)	
Daily or more	340 (16.5)	(14.9, 18.1)		180 (7.1)	(6.2, 8.2)		520 (11.3)	(10.4, 12.2)	
<i>p</i> -trend	0.7204		<i>p</i> = 0.016	0.6680		<i>p</i> = 0.615	0.8560		<i>p</i> = 0.020
Instant food									
Never	1086 (17.4)	(16.4, 18.3)		680 (8.5)	(7.9, 9.1)		1766 (12.4)	(11.8, 12.9)	
1–3 times/month	1087 (14.4)	(13.6, 15.2)		515 (5.5)	(5.1, 6.0)		1602 (9.5)	(9.0, 9.9)	
1–2 times/week	474 (12.3)	(11.3, 13.3)		234 (5.3)	(4.7, 6.0)		708 (8.6)	(8.0, 9.2)	
3–6 times/week	168 (12.8)	(11.1, 14.7)		83 (6.4)	(5.2, 7.9)		251 (9.6)	(8.6, 10.8)	
Daily or more	25 (14.4)	(9.9, 20.4)		13 (6.8)	(4.0, 11.4)		38 (10.4)	(7.7, 14.0)	
<i>p</i> -trend			<i>p</i> < 0.001			<i>p</i> < 0.001			<i>p</i> < 0.001

Participants

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Table 4 (continued)

Participants						
	Male			Female		Total
	n (%)	(95% CI)	p-value	n (%)	(95% CI)	n (%)
5–9	129 (15.8)	(13.5, 18.5)		44 (6.4)	(4.8, 8.5)	173 (11.5)
10–14	7 (9.1)	(4.4, 17.9)		6 (10.0)	(4.6, 20.5)	13 (9.5)
≥ 15	3 (14.3)	(4.7, 36.1)		0 (0)		3 (10.0)
<i>p</i> -trend	0.7897		<i>p</i> = 0.448	0.1844		0.5958
Activity status						
Weekly exercise#						
0–7	819 (18.4)	(17.3, 19.6)		611 (7.8)	(7.2, 8.4)	1430 (11.6)
8–14	924 (14.7)	(14.0, 15.8)		483 (5.9)	(5.4, 6.4)	1407 (9.74)
≥ 15	1034 (12.8)	(12.1, 13.6)		402 (5.96)	(5.4, 6.6)	1436 (9.69)
<i>p</i> -trend	0.1789		<i>p</i> < 0.001	0.4244		0.4003
Housework						
Never	282 (21.4)	(19.3, 23.7)		88 (10.84)	(8.9, 13.2)	370 (17.38)
1–3 times/month	581 (16.1)	(14.9, 17.3)		179 (7.1)	(6.2, 8.2)	760 (12.4)
Once or twice/week	764 (14.5)	(13.5, 15.4)		464 (6.9)	(6.3, 7.5)	1228 (10.2)
3–4 times/week	417 (13.4)	(12.2, 14.6)		231 (6.4)	(5.7, 7.3)	648 (9.64)
Every day or more	777 (13.4)	(12.6, 14.3)		548 (5.7)	(5.3, 6.2)	1325 (8.6)
<i>p</i> -trend	0.0472		<i>p</i> < 0.001	0.0569		0.0269
Sleeping time						
≤ 6 hours	1092 (16.0)	(15.1, 16.9)		617 (7.9)	(7.3, 8.5)	1709 (11.7)
7–8 hours	1361 (13.9)	(13.2, 14.6)		715 (5.8)	(5.4, 6.2)	2076 (9.4)
≥ 9 hours	368 (15.3)	(13.9, 16.8)		187 (6.2)	(5.4, 7.1)	555 (10.3)
<i>p</i> -trend	0.7223		<i>p</i> = 0.001	0.3818		0.5073
Sedentary time						
≤ 7 hours	1757 (14.6)	(14.0, 15.2)		795 (6.3)	(5.9, 6.7)	2552 (10.3)
8–12 hours	947 (15.2)	(14.4, 16.2)		609 (6.7)	(6.2, 7.2)	1556 (10.1)
≥ 13 hours	141 (15.6)	(13.4, 18.1)		123 (8.2)	(6.9, 9.7)	264 (11.0)
<i>p</i> -trend	0.1690		<i>p</i> = 0.401	0.1769		0.4430

Table 4 (continued)

Participants	Male			Female			Total		
	n (%)	(95% CI)	p-value	n (%)	(95% CI)	p-value	n (%)	(95% CI)	p-value
Smoking and Drinking status									
Smoking									
Non-current smoker	2386 (14.8)	(14.3, 15.4)		1511 (6.5)	(6.2, 6.8)		3897 (9.9)	(9.6, 10.2)	
Current smoker	460 (14.9)	(13.6, 16.1)	$p = 0.977$	16 (11.4)	(7.1, 17.7)	$p = 0.02$	476 (14.7)	(13.5, 16.0)	$p < 0.001$
Drinking									
Never	575 (15.3)	(14.2, 16.5)		1049 (6.9)	(6.5, 7.4)		1624 (8.6)	(8.2, 9.0)	
Ex-drinker	597 (19.3)	(17.9, 20.7)		156 (6.8)	(5.9, 7.9)		753 (14.0)	(13.1, 14.9)	
Occasional or social	1393 (13.0)	(12.4, 13.7)		305 (5.3)	(4.7, 5.9)		1698 (10.3)	(9.9, 10.8)	
Current regular	278 (17.1)	(15.4, 19.0)	$p < 0.001$	8 (9.6)	(4.9, 18.1)	$p < 0.001$	286 (16.7)	(15.1, 18.6)	$p < 0.001$
p-trend	0.8804			0.5289			0.2609		

* Life course residence: urbanization status was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralities (rural-rural, RR), urbanizers (rural-urban, RU), de-urbanizers (urban-rural, UR) and urbanites (urban-urban, UU) (Banks et al. 2011; Feng et al. 2020)

Weekly exercise: the combined measure of weekly physical activities: “2 × vigorous exercises + 1 × moderate exercises + 1 × walking sessions per week”, which was on the basis of International Physical Activity Questionnaire and the Active Australia Survey (Banks et al. 2011; Feng et al. 2020; Thawornchaisit et al. 2015; Zhao et al. 2015)

p-trend **bolding**: The results of p-trend were statistical significance (p for trend < 0.05)

to have a lower likelihood of multimorbidity than those living in Bangkok (see Fig. 1).

In terms of dietary consumption, the more frequently individuals consumed instant food (female: p -trend = 0.0301, total: p -trend = 0.0446), the higher their odds of multimorbidity. Similarly, the more frequently people ate fast food (male: p -trend = 0.0346, total: p -trend = 0.0313), the higher the likelihood that they would develop multimorbidity (see Fig. 1).

As for the activity status, weekly moderate and vigorous exercise reduced participants' likelihood of multimorbidity compared to low-intensity exercise (all $p < 0.05$) after controlling for the other variables. Moreover, the more frequently people did housework, the less likely they were to have multimorbidity (male: p -trend = 0.0004; total: p -trend = 0.0034). Participants had higher odds of multimorbidity if they slept less than 6 h (female: AOR = 1.46, 95% CI 1.17–1.83; total: AOR = 1.24, 95% CI 1.09–1.41) or more than 9 h (female: AOR = 1.43, 95% CI 1.04–1.97; total: AOR = 1.29, 95% CI 1.07–1.55) compared with people with 7–8 h of sleep (see Fig. 1).

As for smoking (see Fig. 1), there was no significant difference in the likelihood of multimorbidity between non-current smokers and current smokers. Occasional or social drinkers had lower odds of having multimorbidity in the overall group (AOR = 0.82, 95% CI 0.70–0.95), compared with non-drinkers, after adjusting for socio-demographic and other lifestyle elements (see Fig. 1).

Discussion

In our TCS of community-living adults, the prevalence of multimorbidity in men was higher than that in women. Moreover, Bangkok, the capital, had the highest prevalence of multimorbidity. People who were older, with poor living habits, including frequently consuming instant food and fast food, and with insufficient or excessive sleep time were more likely to suffer from multimorbidity. However, exercise, especially housework and occasional social drinking, could reduce the likelihood of multimorbidity.

Socio-demographic factors and multimorbidity

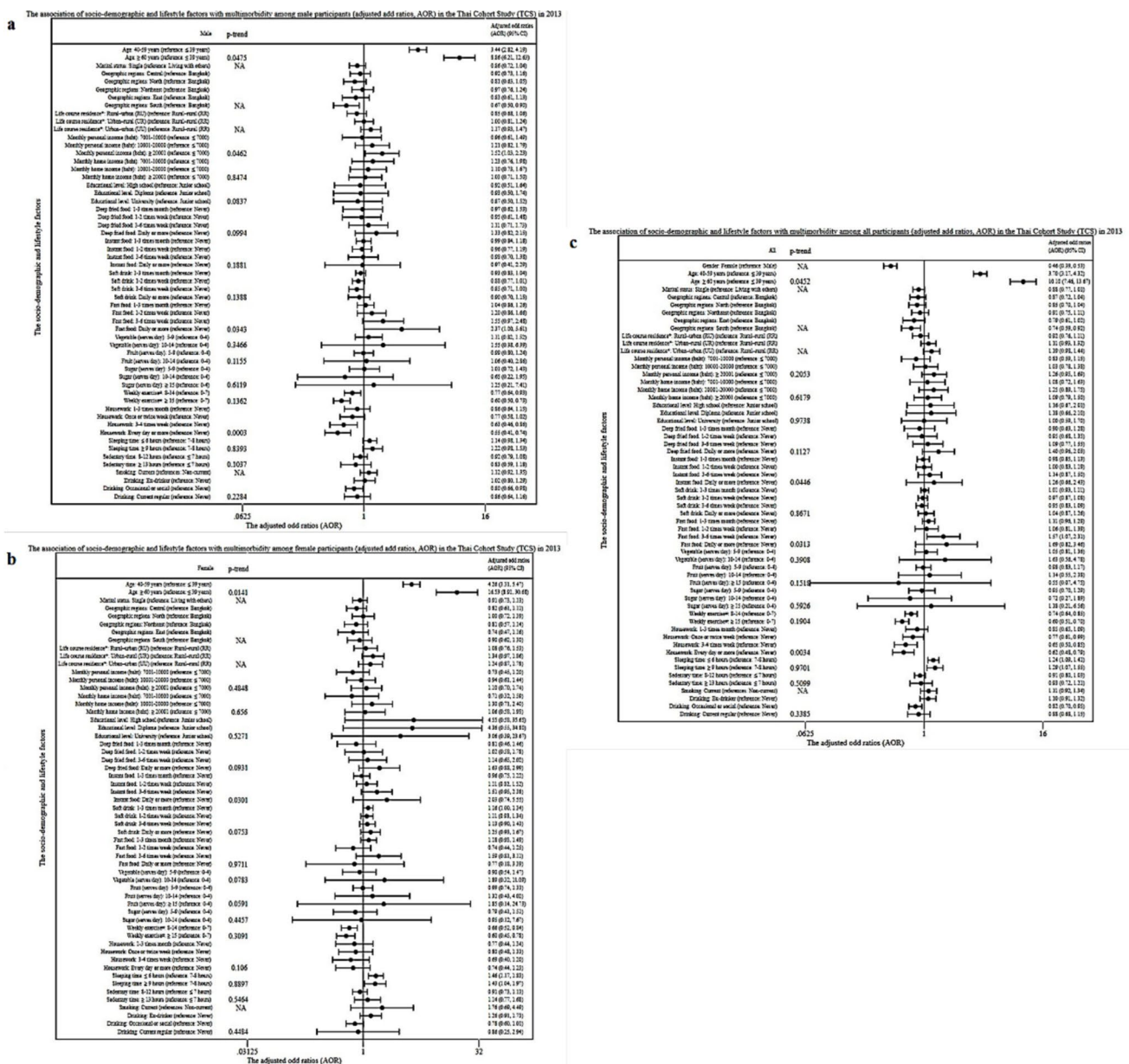
This study showed that the prevalence of multimorbidity was 10.3% among Thai adults, which is lower than the prevalence in other low- and middle-income countries (LMICs) (29.7%) (Nguyen et al. 2019) and the prevalence of multimorbidity in another study (self-reported) in Thailand (20.4%) (Intarut et al. 2021). It is possible that this is due to the lower age of the participants in TCS,

mostly concentrated in the age group of 40 to 59 years. However, the prevalence of multimorbidity increased gradually with age, with a prevalence of 33.7% for those aged 60 years or older, which is more in line with the prevalence of multimorbidity in older adults in LMICs, since age is the most important variable of multimorbidity (Nguyen et al. 2019).

In our study, women were less likely than men to suffer from multimorbidity, which was contrary to the results of another study in Thailand (Intarut et al. 2021). A study in Vietnam showed no association between gender and multimorbidity among people over 15 years old (Ba et al. 2019). The effect of gender on multimorbidity may be complex, and contradictory findings have been identified with the prevalence of multimorbidity being higher in women than in men (Intarut et al. 2021) and that women are more likely to have multimorbidity (Roman Lay et al. 2020). This will still need to be confirmed by further studies, especially longitudinal analysis (Ba et al. 2019; Intarut et al. 2021; Roman Lay et al. 2020). Moreover, the TCS women were significantly more highly educated than the general Thai population and the male participants in the TCS. This may further help to explain the lower multimorbidity prevalence in this group, as more educated women may have better access to health education and thus pay more attention to their own health (Sleigh et al. 2008; Zhao et al. 2015). Although we did not find a relationship between marital status and multimorbidity in this article, there are cross-sectional studies in Thailand (Intarut et al. 2021) and Indonesia (Asturiningtyas et al. 2021) reporting that single people would have lower odds of multimorbidity.

In this study, the capital region had a high prevalence of multimorbidity, which may be related to the level of development in the region. Bangkok is relatively developed and may also be relatively more aged than other regions, which could also be analogous to the prevalence of multimorbidity in high-income countries (HICs) and LMICs (Nguyen et al. 2019). HICs are relatively more developed but more aged and therefore have a higher prevalence of multimorbidity (Nguyen et al. 2019).

Income and education are important indicators of SES. However, in this study, no significant association was found between income, education, and the prevalence of multimorbidity, nor did they form a linear relationship. Nevertheless, a systematic review showed that individuals with lower SES, characterized by lower income and education levels, were more likely to suffer from multimorbidity (Pathirana and Jackson 2018). This may be because people with low SES tend to have poorer health behaviours, such as lower levels of physical



The associations between these socio-demographic and lifestyle factors and multimorbidity were significantly different ($p < 0.05$) and/or the linear trend (p -trend) was significantly different (p for trend < 0.05) after adjusting for confounders (other socio-demographic and lifestyle factors). # Weekly exercise: the combined measure of weekly physical activity, i.e. $2 \times$ vigorous exercise + $1 \times$ moderate exercise + $1 \times$ walking sessions per week, on the basis of International Physical Activity Questionnaire and the Active Australia Survey (Banks et al. 2011; Feng et al. 2020; Thawornchaisit et al. 2015; Zhao et al. 2015). NA: not available, AOR: adjusted odds ratio, adjusting for other socio-demographic and lifestyle factors

Fig. 1 The association of socio-demographic and lifestyle factors with multimorbidity among participants (AOR) (**a** for male, **b** for female, and **c** for all) in the Thai Cohort Study (TCS) in 2013

activity and an unbalanced diet, which increases their risk of developing multimorbidity (Feng et al. 2021; Pathirana and Jackson 2018). However, another systematic analysis conducted in Southeast Asia found that the relationship between education level and multimorbidity is more complex (Feng et al. 2021). Specifically,

higher education levels, which are generally associated with higher income, may either increase or decrease the prevalence of multimorbidity or have no significant effect (Feng et al. 2021). Therefore, further research is needed to explore the relationship between SES and multimorbidity.

Dietary consumption and multimorbidity

Although the consumption of most foods was not associated with multimorbidity, the more frequently people consumed fast food and instant foods, the more likely they were to have multimorbidity. These results align with those of a cross-sectional study by Pelotas on diet and multimorbidity (Pereira et al. 2020). Furthermore, increasing evidence suggests that a mono-structured diet (Chudasama et al. 2020; Ruel et al. 2014; Zhang et al. 2022), a meat-dominated diet, and dietary patterns with inadequate intake of fruits, vegetables, and grains (Chudasama et al. 2020; Ruel et al. 2014; Zhang et al. 2022) may be associated with an increased likelihood of multimorbidity. However, as our study is cross-sectional, it is not possible to establish whether these dietary habits preceded or resulted from the onset of multimorbidity. Notably, while our study found no relationship between soft drink consumption and the prevalence of multimorbidity, a cross-sectional study in South Australia identified a positive association between soft drink consumption and multimorbidity (Shi et al. 2015).

Activity status and multimorbidity

Physical activity is inversely correlated with multimorbidity. This phenomenon was confirmed in cross-sectional studies in Brazil (Christofolletti et al. 2021) and Singapore (Subramaniam et al. 2019). In our study, housework, which is a type of exercise, also clearly reduced the odds of multimorbidity. Although there is little research on the relationship between multimorbidity and housework (household cleaning and gardening work), housework is also a form of exercise and may be associated with exercise to reduce people's odds of developing multimorbidity. Exercise has cardiovascular benefits, which can effectively reduce high blood pressure and high blood cholesterol and aid in weight control (Christofolletti et al. 2021; Subramaniam et al. 2019). Similarly, sedentary individuals may be more susceptible to multimorbidity (Loprinzi 2015), although such results were not significant in our study. In addition, the results of a cross-sectional study in Luxembourg showed a positive association between multimorbidity and insufficient or excessive sleep (Ruiz-Castell et al. 2019), which would be like the results of the association between sleep duration and multimorbidity in our study.

Smoking and drinking, and multimorbidity

In terms of smoking and drinking status, there was no association between smoking and multimorbidity in our study. However, in a Canadian study, smoking was associated with an increased likelihood of multimorbidity in men (Fortin et al. 2014), but in a South African study, smoking was

associated with a decreased likelihood of multimorbidity (Alaba and Chola 2013). Furthermore, there was a negative association between occasional or social drinking and multimorbidity in this paper, which was similar to the findings of a study in Canada that daily or weekly alcohol intake was associated with a lower likelihood of having multimorbidity (Sakib et al. 2019). Other studies have shown that there was no association between the intake of alcohol and multimorbidity, which may be due to the fact that as a cross-sectional study, a causal relationship between alcohol and multimorbidity could not be inferred. It is possible that the participants with multimorbidity have abstained from alcohol due to health concerns (Sakib et al. 2019). Therefore, a longitudinal study to investigate the causal relationship between the amount of alcohol intake and multimorbidity is necessary.

Strengths, limitations, and future research

This paper is the first to use the TCS to analyse the association between risk factors and multimorbidity. TCS was a relatively mature and comprehensive study of health transitions in Thailand, with broad and rich coverage, a large sample size living throughout the country, and a relatively broad population (Feng et al. 2020).

However, there are still some limitations. First, as mentioned previously, the participants (STOU students) in the TCS were relatively young and highly educated compared to the general Thai population. This over-representation of younger, more educated individuals may have led to an underestimation of the prevalence of multimorbidity, as older adults and those with lower SES are more likely to experience multimorbidity (Pathirana and Jackson 2018). Therefore, the findings from this study should be interpreted with caution when attempting to generalize to the broader Thai population, particularly those from lower socio-economic backgrounds. It is also worth noting that the TCS participants may represent the next generation of Thais as the country's population becomes more educated (Thawornchaisit et al. 2015). However, the results may not fully reflect the diversity of the Thai general population, and further studies using more representative samples are needed to validate our findings. Furthermore, we have incorporated findings from Intarut et al. (2021), based on the general Thai population, to compare socio-demographic factors such as gender and marital status, which are also related to multimorbidity. These comparisons help contextualize our results and provide further insights into potential selection bias when extrapolating our findings.

Secondly, we used TCS data collected in 2013, which are relatively old, and disease patterns may have changed.

Since the TCS is self-reported, this may lead to recall bias (Feng et al. 2020; Thawornchaisit et al. 2013). However, a series of validation studies have been carried out with TCS participants to confirm the self-report of disease status, and these have found high accuracy in self-reporting (Papier et al. 2016).

The other limitation is that dietary intake was assessed by frequency of consumption (e.g. fast food, instant food) but lacked details on portion size or nutrient composition in this study. This may impact the accuracy in assessing overall dietary patterns and their relationship with multimorbidity.

In addition, given the cross-sectional nature of this study, which is based solely on data from the 2013 TCS, the observed associations should be interpreted cautiously as hypothesis-generating rather than confirming causal relationships. This design does not allow for the investigation of causality (Fortin et al. 2010). Moreover, regarding the measurement of multimorbidity, we considered 12 common NCDs in the TCS, which may have an impact on the prevalence estimates of multimorbidity. Some relevant studies have suggested that a higher number of diseases in the multimorbidity list may lead to higher multimorbidity prevalence estimates (Fortin et al. 2014). At the same time, a limitation of this study is the exclusion of certain chronic conditions, such as musculoskeletal conditions and mental health disorders, which may lead to an underestimation of the true prevalence of multimorbidity (Fortin et al. 2014; Willadsen et al. 2016).

In future studies, it would be valuable to focus on the current Thai population and conduct longitudinal research to better understand these relationships and explore potential reverse causality. Additionally, due to the ageing in Thailand, research on multimorbidity should be increased in collaboration with the local Thai government with the aim of prevention and treatment of multimorbidity.

Moreover, further studies using more representative, population-based samples are essential to confirm the findings of this study. These studies also should include a broader range of chronic conditions including musculoskeletal disorders and mental illnesses, and incorporate more detailed dietary data, including portion sizes and nutrient composition to provide a more comprehensive assessment of multimorbidity.

Although this study did not analyse interactions among risk factors, our primary focus was to conduct an initial descriptive exploration and examine the independent effects of each factor. This approach provides a foundation for further investigations. Future research incorporating interaction effects could offer deeper insights into how different risk factors contribute to multimorbidity.

Conclusion

In conclusion, in the Thai Cohort Study, the prevalence of multimorbidity was lower in women than in men. Older age, preferring instant food and fast food, and irregular sleep schedule may be associated with higher odds for multimorbidity, but the odds of multimorbidity could be reduced with social-occasional drinking and moderate-to-vigorous exercise, especially housework in total members, which was inversely related to the prevalence of multimorbidity. Further research is needed to determine the causal relationship between these factors and multimorbidity. Furthermore, it is hoped that the Thai government, while paying attention to single diseases, would not ignore the existence of multimorbidity, and that they urge people to change their poor habits, eat less fast food, get a normal amount of sleep, and actively participate in physical exercise, especially housework and garden work, to effectively control the occurrence of multimorbidity.

Abbreviations AOR: Adjusted odds ratio; BMI: Body mass index; LMICs: Low- and middle-income countries; HICs: High-income countries; NCDs: Non-communicable diseases; OR: Odds ratio; SES: Socio-economic status; STOU: Sukhothai Thammathirat Open University; TCS: Thai Cohort Study; 95% CI: 95% Confidence interval

Supplementary Information The online version contains supplementary material available at <https://doi.org/10.1007/s10389-025-02479-0>.

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Authors' contributions Conceptualization: XF; Data curation: XF, HS and MK; Formal analysis: XF; Methodology: XF, HS and MK; Project administration: HS and MK; Resources: SS, AS and MK; Supervision: XF, HS and MK; Validation: XF, HS and MK; Writing—original draft: XF; Writing—review & editing: XF, HS and MK.

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Data availability Data may be requested from the authors if the reason is relevant and sufficient.

Declarations

Ethics approval The Thai Cohort Study (TCS) has been approved by the ethics committee of the Sukhothai Thammathirat Open University Research and Development Institute (protocol number: 0522/10). For this subsample analysis, we also obtained approval from the Human Research Ethics Committee of the Australian National University (protocol number: 2004/344, 2009/570, 2021/796).

Consent to participate Informed consent was obtained from all individuals who participated in the study.

Conflict of interest None.

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Association of socio-demographic and lifestyle factors with multimorbidity among adults in the Thai Cohort Study

Table S1 The association of socio-demographic and lifestyle factors with multimorbidity among the participants (unadjusted regression/crude odd ratios) in the Thai Cohort Study (TCS) in 2013

	Male		Female		Total	
	OR	(95 % CI)	OR	(95 % CI)	OR	(95 % CI)
Socio-Demographic factors						
Gender	1.00		0.40	(0.38, 0.43)		
Age						
≤ 39	1.00		1.00		1.00	
40-59	3.67	(3.32, 4.06)	4.42	(3.92, 4.98)	4.35	(4.03, 4.70)
≥ 60	7.71	(6.45, 9.21)	15.74	(11.89, 20.82)	11.69	(10.08, 13.57)
p-trend	0.0312		0.0566		0.0492	
Marital status						
Living with others	1.00		1.00		1.00	
Single	0.61	(0.55, 0.67)	0.98	(0.88, 1.09)	0.66	(0.62, 0.71)
Geographic regions						
Bangkok	1.00		1.00		1.00	
Central	0.84	(0.74, 0.96)	0.79	(0.68, 0.91)	0.85	(0.77, 0.93)
North	0.69	(0.60, 0.79)	0.60	(0.51, 0.71)	0.72	(0.65, 0.79)
Northeast	0.72	(0.64, 0.82)	0.58	(0.49, 0.68)	0.76	(0.69, 0.84)
East	0.69	(0.58, 0.83)	0.50	(0.40, 0.63)	0.65	(0.57, 0.75)
South	0.59	(0.51, 0.70)	0.53	(0.44, 0.64)	0.59	(0.52, 0.67)
Life course residence*						
Rural–rural (RR)	1.00		1.00		1.00	
Rural–urban (RU)	0.87	(0.71, 1.06)	1.04	(0.76, 1.42)	0.87	(0.74, 1.02)
Urban–rural (UR)	1.32	(1.10, 1.58)	1.73	(1.30, 2.29)	1.35	(1.16, 1.57)
Urban–urban (UU)	1.30	(1.06, 1.60)	1.44	(1.04, 1.99)	1.28	(1.08, 1.52)
Monthly personal income (baht)						
≤ 7000	1.00		1.00		1.00	
7001-10000	0.70	(0.56, 0.87)	0.70	(0.55, 0.89)	0.67	(0.57, 0.78)
10001-20000	0.85	(0.72, 1.00)	0.82	(0.67, 0.99)	0.83	(0.73, 0.94)
≥ 20001	1.78	(1.53, 2.08)	1.76	(1.46, 2.12)	1.94	(1.72, 2.18)
p-trend	0.2115		0.2254		0.2049	
Monthly home income (baht)						
≤ 7000	1.00		1.00		1.00	

7001-10000	0.88	(0.68, 1.13)	0.81	(0.57 1.15)	0.79	(0.65, 0.97)
10001-20000	0.86	(0.70, 1.05)	0.96	(0.73 1.27)	0.82	(0.69, 0.96)
≥ 20001	1.45	(1.22, 1.72)	1.46	(1.13 1.89)	1.38	(1.20, 1.59)
p-trend	0.2433		0.1877		0.3041	
Educational level						
Junior school	1.00		1.00		1.00	
High school	0.73	(0.52, 1.04)	0.79	(0.40 1.53)	0.68	(0.50, 0.92)
Diploma	0.76	(0.52, 1.10)	0.96	(0.49 1.87)	0.70	(0.51, 0.97)
University	0.91	(0.65, 1.27)	0.76	(0.39 1.45)	0.71	(0.53, 0.95)
p-trend	0.7566		0.4088		0.2789	
Health behaviours/Personal lifestyles						
Diet consumptions						
Deep fried food						
Never	1.00		1.00		1.00	
1-3 times/month	0.95	(0.73, 1.23)	0.87	(0.64, 1.18)	0.93	(0.76, 1.13)
1-2 times/week	0.82	(0.63, 1.05)	0.84	(0.62, 1.13)	0.85	(0.70, 1.03)
3-6 times/week	0.86	(0.67, 1.10)	0.87	(0.64, 1.17)	0.92	(0.76, 1.11)
Daily or more	0.99	(0.76, 1.29)	0.94	(0.68, 1.30)	1.01	(0.82, 1.23)
p-trend	0.7260		0.6339		0.9692	
Instant food						
Never	1.00		1.00		1.00	
1-3 times/month	0.80	(0.73, 0.88)	0.63	(0.56, 0.71)	0.74	(0.69, 0.80)
1-2 times/week	0.67	(0.59, 0.75)	0.60	(0.52, 0.70)	0.66	(0.60, 0.73)
3-6 times/week	0.70	(0.59, 0.83)	0.74	(0.59, 0.94)	0.76	(0.66, 0.87)
Daily or more	0.80	(0.52, 1.23)	0.79	(0.45, 1.40)	0.83	(0.59, 1.16)
p-trend	0.2725		0.6237		0.5106	
Soft drink						
Never	1.00		1.00		1.00	
1-3 times/month	0.75	(0.68, 0.83)	0.87	(0.77, 0.99)	0.86	(0.80, 0.93)
1-2 times/week	0.65	(0.58, 0.73)	0.76	(0.64, 0.89)	0.78	(0.71, 0.85)
3-6 times/week	0.61	(0.52, 0.70)	0.79	(0.65, 0.97)	0.76	(0.68, 0.86)
Daily or more	0.67	(0.55, 0.82)	1.04	(0.82, 1.33)	0.86	(0.73, 1.00)
p-trend	0.0965		0.8606		0.2486	
Fast food						

Never	1.00			1.00			1.00		
1-3 times/month	0.97	(0.88, 1.08)		1.12	(0.99, 1.26)		0.98	(0.91, 1.05)	
1-2 times/week	0.94	(0.78, 1.13)		0.90	(0.70, 1.16)		0.91	(0.79, 1.06)	
3-6 times/week	1.37	(1.06, 1.78)		0.95	(0.63, 1.45)		1.25	(1.00, 1.55)	
Daily or more	1.57	(0.97, 2.55)		0.87	(0.38, 2.00)		1.32	(0.88, 1.99)	
p-trend	0.0625			0.1960			0.1801		
Vegetable (serves/day)									
0-4	1.00			1.00			1.00		
5-9	0.85	(0.71, 1.02)		0.87	(0.68, 1.11)		0.88	(0.77, 1.02)	
10-14	0.87	(0.39, 1.92)		1.69	(0.67, 4.28)		1.18	(0.65, 2.16)	
≥ 15	0.32	(0.04, 2.37)		0			0.33	(0.05, 2.46)	
p-trend	0.0667			0.1032			0.2816		
Fruit (serves/day)									
0-4	1.00			1.00			1.00		
5-9	0.94	(0.83, 1.06)		0.80	(0.69, 0.93)		0.82	(0.75, 0.90)	
10-14	0.69	(0.39, 1.20)		0.93	(0.53, 1.64)		0.74	(0.50, 1.10)	
≥ 15	0.74	(0.22, 2.47)		0.63	(0.08, 4.66)		0.75	(0.27, 2.10)	
p-trend	0.2224			0.1341			0.3448		
Sugar (serves/day)									
0-4	1.00			1.00			1.00		
5-9	1.08	(0.89, 1.31)		0.98	(0.72, 1.33)		1.14	(0.97, 1.34)	
10-14	0.57	(0.26, 1.25)		1.58	(0.68, 3.69)		0.92	(0.52, 1.63)	
≥ 15	0.96	(0.28, 3.25)		0			0.97	(0.29, 3.21)	
p-trend	0.7872			0.1734			0.5821		
Activity status									
Weekly exercise#									
0-7	1.00			1.00			1.00		
8-14	0.77	(0.70, 0.86)		0.74	(0.65, 0.83)		0.82	(0.76, 0.89)	
≥ 15	0.65	(0.59, 0.72)		0.75	(0.66, 0.85)		0.82	(0.75, 0.88)	
p-trend	0.1955			0.4196			0.4146		
Housework									
Never	1.00			1.00			1.00		
1-3 times/month	0.70	(0.60, 0.83)		0.63	(0.48, 0.83)		0.67	(0.59, 0.77)	
Once or twice/week	0.62	(0.53, 0.72)		0.61	(0.48, 0.78)		0.54	(0.48, 0.62)	

3-4 times/week	0.57	(0.48, 0.67)	0.56	(0.44, 0.73)	0.51	(0.44, 0.58)
Every day or more	0.57	(0.49, 0.66)	0.50	(0.39, 0.63)	0.45	(0.40, 0.51)
p-trend	0.0560		0.0612		0.0340	
Sleeping time						
≤ 6 hours	1.18	(1.08, 1.29)	1.40	(1.25, 1.57)	1.28	(1.20, 1.37)
7-8 hours	1.00		1.00		1.00	
≥ 9 hours	1.12	(0.99, 1.27)	1.08	(0.91, 1.27)	1.11	(1.00, 1.22)
p-trend	0.7145		0.3812		0.5151	
Sedentary time						
≤ 7 hours	1.00		1.00		1.00	
8-12 hours	1.05	(0.97, 1.15)	1.06	(0.95, 1.19)	0.98	(0.92, 1.05)
≥ 13 hours	1.08	(0.90, 1.30)	1.33	(1.09, 1.62)	1.07	(0.94, 1.22)
p-trend	0.1320		0.1834		0.4283	
Smoking and drinking status						
Smoking						
Non-current smoker	1.00		1.00		1.00	
Current smoker	1.00	(0.90, 1.12)	1.84	(1.09, 3.10)	1.57	(1.41, 1.74)
Drinking						
Never	1.00		1.00		1.00	
Ex-drinker	1.32	(1.16, 1.50)	0.98	(0.83, 1.17)	1.73	(1.57, 1.89)
Occasional or social	0.83	(0.75, 0.92)	0.75	(0.66, 0.86)	1.22	(1.14, 1.31)
Current regular	1.14	(0.98, 1.33)	1.43	(0.69, 2.98)	2.14	(1.86, 2.45)
p-trend	0.8760		0.5176		0.2674	

Life course residence*: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) (Banks et al., 2011; Feng et al., 2020; Thawornchaisit et al., 2015; Zhao et al., 2015).

Weekly exercise#: The Combined measure of weekly physical activities: “2 × vigorous exercises + 1 × moderate exercises + 1 × walking sessions per week”, which was on the basis of International Physical Activity Questionnaire and the Active Australia Survey (Banks et al, 2011; Feng et al, 2020; Thawornchaisit et al, 2015; Zhao et al, 2015).

p-trend **bolding**: The results of p-trend were statistical significance (p for trend < 0.05).

Chapter 7 The spatial analysis of multimorbidity in Thailand

The previous chapter examined the risk factors associated with multimorbidity in Thailand, including social and lifestyle determinants. While these analyses identified populations at higher risk, they did not account for potential geographical variations in multimorbidity prevalence across the country.

Building on the findings from Chapter 6, this chapter focuses on regional disparities in multimorbidity prevalence in Thailand and aims to identify areas with particularly high prevalence. Spatial analysis allows the identification of “hotspot” regions where multimorbidity is concentrated. Understanding the spatial distribution of multimorbidity is essential because regional differences may reflect variations in demographic composition and socio-economic conditions. Identifying these patterns can guide targeted interventions, optimize healthcare resource allocation, and inform the development of context-specific public health policies tailored to the needs of different regions.

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

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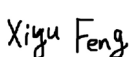
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RESEARCH

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The spatial analysis of multimorbidity in Thai Cohort Study

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Abstract

Background This study used Thai Cohort Study (TCS) data to investigate the spatial and sociodemographic determinants of multimorbidity (two or more chronic conditions coexistence on one person) prevalence in Thailand in 2013.

Methods Crude and age-adjusted prevalence were calculated for each province. Hotspot analysis was conducted to identify regions with statistically significant hotspots and cold spots, including areas without significant clustering. Then, ordinal logistic regression was used to identify sociodemographic background variables that predict hotspots.

Results The highest age-adjusted provincial level prevalence of multimorbidity was in Sing Buri (18.26%). Sak Lek District in Pichit Province also had the highest age-adjusted district level prevalence of multimorbidity at 37.13%. The cold spots region in crude and age-adjusted prevalence of multimorbidity were clustered in Southern Thailand. Forty-eight districts were identified as hotspots in both crude and age-adjusted multimorbidity prevalence, 19 of which are in Bangkok (the capital). Population density (person/km², odd ratio, provincial level: OR:1.00, 95% CI: 1.00–1.01; district level: OR: 1.01, 95% CI: 1.00–1.01), Aging index (provincial level: OR:1.03, 95% CI: 1.01–1.04; district level: OR: 1.01, 95% CI: 1.00–1.01), and average educational years (provincial level: OR:1.92, 95% CI: 1.07–3.48; district level: OR: 1.27, 95% CI: 1.02–2.26) were greater in hot spots areas.

Conclusion This study shows that the prevalence of multimorbidity in Thailand is positively correlated with the degree of development of the region. Spatial cluster analysis provides new evidence for policymakers to design tailored interventions to target multimorbidity and allocate health resources to areas of unmet need.

Keywords Hotspots, Multimorbidity, Non-communicable diseases, Thai Cohort Study, Spatial analysis

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Text box 1. Contributions to literature

- There is limited evidence on multimorbidity and its prevalence in developing countries is lacking.
- Spatial analysis and quantifying socio-demographic background factors confirm that the places with high prevalence of multimorbidity in Thailand are concentrated in developed areas such as the capital.
- Prevention and intervention treatment of multimorbidity specified by regional prevalence differences are necessary.

Introduction

Multimorbidity, defined as the coexistence of two or more chronic diseases in an individual, is becoming increasingly common with global population ageing [1]. It leads to reduced physical functioning and quality of life, increased healthcare costs and disease burden, and a higher risk of disability and mortality in adults [2]. Consequently, multimorbidity has emerged as a major challenge to global public health [3].

The prevalence of multimorbidity is not uniformly distributed across geographical regions. Spatial analyses play a critical role in understanding health conditions across different areas by providing insights into the social and environmental determinants of disease prevalence [4]. When applied to multimorbidity, spatial analysis helps identify geographic clusters with elevated prevalence and evaluates the contextual and environmental factors contributing to these patterns [5].

Similar to many low- and middle-income countries (LMICs), Thailand is undergoing a health transition, with the rising prevalence of multimorbidity driven by demographic shifts, lifestyle changes, and urbanization, posing significant challenges to the healthcare system [3]. For instance, multimorbidity may be more prevalent in economically developed regions [4, 6]. However, few studies have investigated its spatial distribution within Thailand [6]. Understanding this distribution is essential for identifying high-risk areas, assessing environmental risk factors, and developing targeted interventions for affected populations [6–8].

Spatial analysis of multimorbidity can inform evidence-based decision-making by pinpointing “hotspot” areas where interventions can be prioritized to optimize healthcare delivery and resource allocation [9, 10]. Furthermore, understanding the spatial distribution of multimorbidity supports the development of context-specific policies and strategies tailored to the unique challenges of different regions [11]. The aim of this study is twofold: (1) to examine the geographic variation of multimorbidity in Thailand, and (2) to quantify the potential impact of socio-demographic contextual factors on areas with a higher risk of multimorbidity. We hypothesize that the distribution of multimorbidity is not random but shows

distinct geographic clustering, with higher prevalence in areas characterized by specific socio-demographic attributes.

Methods**The study population**

The Thai Cohort Study (TCS) is a nationwide project aimed at investigating Thailand’s ongoing health risk transition, which refers to the shift in disease burden from infectious diseases to non-communicable diseases (NCDs). Launched in 2005, the project has successfully enlisted over 87,000 individuals who initially enrolled at Sukhothai Thammathirat Open University (STOU) in Thailand [12, 13]. The participants in this study were drawn from across the country and spanned an age range of 15 to 87 years at baseline. These respondents were reasonably representative of both STOU’s student population and the broader Thai population in terms of median age, income, regional distribution and ethnic diversity [14]. However, it’s worth noting that this cohort displayed a lower mean age (around 41 years old) and boasted a higher level of education compared to the average adult population in Thailand [15]. Additionally, a larger proportion of STOU students were residing in urban areas [15].

Study design and data collection

Data were collected through three mailed questionnaires. The first was in 2005 (baseline) and the follow-up surveys were in 2009 (midpoint) and 2013 (endpoint). At each round of follow-up, approximately 70% of cohort members were retained in the study [14, 15]. The present study is a cross-sectional study based on the 2013 mailed questionnaire, which surveyed a total of 42,785 respondents to obtain district (second administrative level) and province (first administrative level) information from their home addresses [14, 15].

The definition of multimorbidity

In this research, multimorbidity refers to the concurrent presence of two or more chronic diseases in an individual. This widely adopted definition is commonly used in epidemiological studies [15]. During the 2013 follow-up survey, respondents were asked if a physician had diagnosed them with any of eleven specified diseases. A “yes” response indicated the presence of these conditions, while “no” denoted their absence [15]. These eleven diseases encompassed diabetes, high cholesterol, hypertension, ischemic (coronary) heart disease, stroke, kidney disease, liver cancer, lung cancer, stomach cancer, colon cancer, and breast cancer. Additionally, participants provided their height and weight, allowing for the calculation of the body mass index (BMI) [15]. BMI values were classified based on the specific cut-off for Asian

populations, where individuals with a BMI over 25 kg/m² were considered obese, following the World Health Organization (WHO) recommendations for this group [16]. Therefore, multimorbidity was determined when an individual reported "yes" for two or more of these twelve conditions (which included obesity) [15, 16].

Spatial data

The administrative boundaries, used as the spatial unit of analysis were downloaded from the Human Data Exchange-Thailand—Subnational Administrative Boundaries [17]. The province level is the first administrative level in Thailand, with 76 in total. Bangkok, as the capital, is the special administrative area and is not classified as a province (Bangkok has 50 districts). The second administrative level is the districts, of which there are 878 (the 50 districts of the capital being not included) [18].

To improve accuracy, we only analysed multimorbidity prevalence in Provinces or Districts where 6 or more TCS participants resided [18]. All Thai provinces (including the Capital Special Administrative Region) had more than five participants, but only 870 of the 928 districts (including the 50 districts in capital) had more than five participants. We listed the 58 districts with less than or equal to 5 participants as blank.

Age-adjusted multimorbidity prevalence

Due to data limitations and differences in age structure between the Thai Cohort Study (TCS) and the national population, we calculated both crude and age-standardized multimorbidity prevalence at the district and provincial levels [4, 18]. Age-standardized prevalence was derived using demographic data from the 2013 Thai capital region, provinces, and districts obtained from the National Statistics Office [19] and Official registration systems [20]. We first calculated the percentage of the population in each age group based on national data. Then, the crude prevalence of multimorbidity for each age group within the TCS sample across capital areas, provinces, and districts was standardized using the national age structure. Specifically, the crude prevalence for each age group in the TCS was multiplied by the corresponding population proportion from national data, and the results were summed to obtain the age-adjusted prevalence [4]. These adjusted and crude prevalence estimates were subsequently mapped using ArcGIS Pro 2.6 (ESRI, Redlands, CA).

Spatial analysis of multimorbidity

Spatial Autocorrelation (Global Moran's I)

The Global Moran's I statistic was used to assess whether there was a clustering of multimorbidity prevalence across districts and provinces in Thailand. The null

hypothesis was that multimorbidity was randomly distributed across districts and provinces. The Global Moran's I value generally ranged from -1 (perfect dispersion) to $+1$ (perfect clustering). The Global Moran's I value would be used in conjunction with the G statistic to provide a better understanding of local spatial patterns [4, 18, 21].

High/Low Clustering (Getis-Ord General G)

Since Global Moran's I can assess spatial autocorrelation but cannot specifically determine high or low clustering, the Getis-Ord General G index is used to better identify the clustering of spatial data. In other words, Getis-Ord General G examines whether districts and provinces with similar multimorbidity prevalence are spatially clustered together. Similar to Global Moran's I, the Getis-Ord General G value ranges from -1 to 0 , indicating low clustering (areas with dissimilar prevalence), and from 0 to $+1$, indicating high clustering (areas with similar prevalence). A value of 0 represents randomness, meaning no significant clustering is present [4, 18, 21].

Hotspot analysis (Getis-Ord Gi)*

The study utilized the Getis-Ord Gi* statistic in conducting Hotspot analysis to pinpoint statistically significant areas of multimorbidity prevalence within Thailand's districts and provinces. Within this context, a hotspot indicated a cluster of high prevalence (indicated by shades of red on map), while a cold spot denoted a cluster of low prevalence (indicated by shades of blue on map). The adjacent regions that are not statistically significant were displayed in white on the map [18, 22]. Spatial weights were assigned using contiguity edges corners technique. Contiguity defines neighbouring polygons as those touching each other, including polygons that share edges or corners, which are considered neighbours in the analysis. To address variations in neighbour counts among features, the study used row standardization to create proportional weights [18].

Statistical analysis

We used ordinal logistic regression to investigate the impact of socio-demographic contextual factors, including population density (persons/km²) [17, 23], aging index (an indicator comparing the ratio of elderly population (aged 60 and above) to child population (under 15 years old)) [19, 20], monthly average income per household (Baht) [19, 24–26], average annual personal income (Baht) [25–28], the poverty line (expenditure, Baht) [19, 24–26], average years of education [24, 28, 29], and housing density (n/km²) [24, 26, 28] on the adjusted prevalence of multimorbidity hotspot areas. Ordinal logistic regression was chosen because the dependent variables (the

geographic classification of multimorbidity hotspots), is inherently ordinal, with “2” representing hot spots, “1” for non-significant areas, and “0” for cold spots. This method allowed us to examine the impact of these contextual indicators on hot spots, cold spots, and non-significant areas. Comparing to ordinal logistic regression, the logistic regression with binary outcome would collapse categories, losing important information, while multinomial logistic regression treats categories as unordered, ignoring their natural progression. As for spatial autoregressive models, they were not necessary for our study as our dependent variable is ordinal, not continuous. Our focus is on examining socio-demographic factors influencing multimorbidity hotspots, rather than spatial dependence between regions. And we have already used hotspot analysis to capture the spatial distribution. These contextual indicators for 2013, at the provincial and/or district level, were obtained from the website of the Thai government and relevant authorities. The analysis was performed using Stata statistical software (version 16.0, Stata Corp, College Station, Texas, USA).

Results

The characteristics of members in Thai Cohort Study (TCS)

Table 1 presents the characteristics of the 2013 Thai Cohort Study (TCS), which included 42,785 members, with more females (23,455) than males (19,330). The largest age group was under 39 years (51.3%). Fewer people were single (36.0%) than living with partners (64.0%). The East region had the lowest population (8.0%). About 79.7% had some university education. Regarding income, 9.6% earned less than 7,000 Baht per month, while 69.2% lived in households earning over 20,000 Baht monthly.

Spatial analysis of multimorbidity prevalence

The crude prevalence of multimorbidity by province (Fig. 1A) showed that 47 provinces have a crude prevalence of less than 10%, with the lowest being Ranong Province at 3.51%, and the highest being Sing Buri Province at 15.82%. As for the crude prevalence of multimorbidity in districts (Fig. 1C), 178 districts had zero crude prevalence rate, while Don Chedi District in Suphan Buri Province had the highest crude prevalence of multimorbidity at about 54.55%.

In terms of the age-adjusted prevalence of multimorbidity, Fig. 1B indicated that the highest prevalence was Sing Buri Province (18.26%), but the lowest age-adjusted prevalence of multimorbidity was Ranong Province (2.20%). Sak Lek district in Phichit Province had the highest age-adjusted prevalence of multimorbidity at 37.13% but there were also 178 districts with zero age-adjusted prevalence of multimorbidity (Fig. 1D).

Table 1 Demographic and health characteristics of individuals in Thai Cohort Study (TCS) in 2013

Factors	N	Percent (%)
Participants	42,785	100
Age (years) means (SD)	40.50 (8.5)	
Gender		
Male	19,330	45.2
Female	23,455	54.8
Age groups (years)		
≤ 39	21,938	51.3
40–59	19,876	46.5
≥ 60	971	2.3
Marital status		
Living with partner	26,987	64.0
Single	15,167	36.0
Geographic regions		
Bangkok	6742	15.8
Central	9684	22.6
North	8592	20.1
Northeast	8965	21.0
East	3431	8.0
South	5371	12.6
Socioeconomic status		
Educational level		
Junior school	372	0.90
High school	5436	12.8
Diploma	2814	6.6
University	33,940	79.7
Monthly personal income (Baht) (1 US dollar ≈ 35 Baht in 2013)		
≤ 7000	4080	9.60
7001–10 000	5320	12.6
10 001–20 000	15,834	37.4
≥ 20 001	17,087	40.4
Monthly household income (Baht)		
≤ 7000	2608	6.2
7001–10 000	2670	6.3
10 001–20 000	7748	18.3
≥ 20 001	29,271	69.2

The spatial analysis

In assessing the spatial autocorrelation of multimorbidity by province and district, the Global Moran's I test revealed statistically significant clustering patterns ($p < 0.05$) between provinces and districts in both crude (provinces: Moran's I: 0.19, z-score: 2.69, $p < 0.05$; districts: Moran's I: 0.09, z-score: 3.90, $p < 0.001$) and age-adjusted prevalence (provinces: Moran's I: 0.11, z-score: 1.72, $p < 0.1$; districts: Moran's I: 0.11, z-score: 5.22, $p < 0.001$) of multimorbidity.

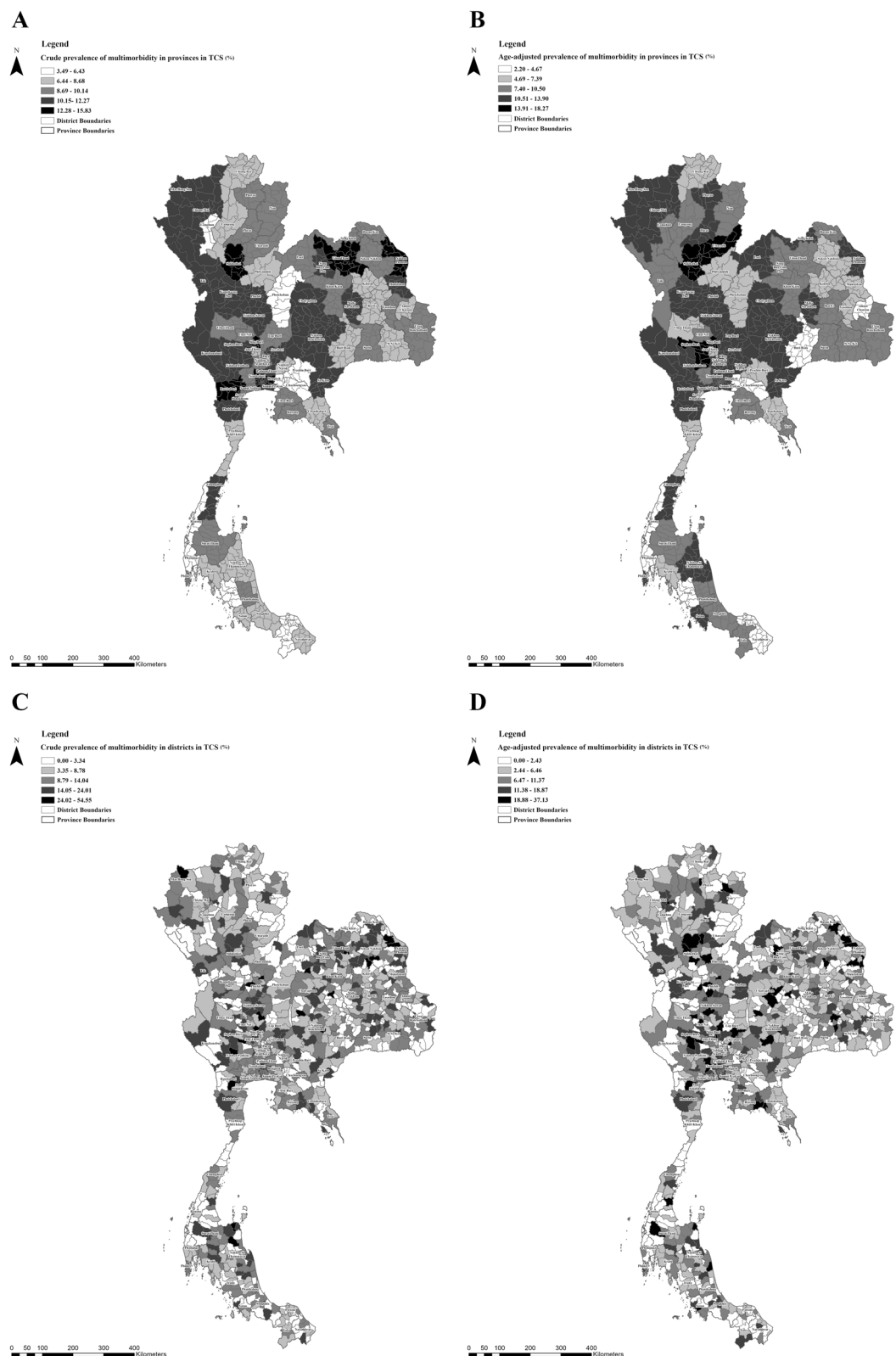


Fig. 1 Geographic distribution of multimorbidity prevalence in Thai Cohort Study (TCS) in 2013. Figure 1 A Crude prevalence of multimorbidity by provinces in TCS; Fig. 1 B Age-adjusted prevalence of multimorbidity by provinces in TCS; Fig. 1 C Crude prevalence of multimorbidity by districts in TCS and Fig. 1 D Age-adjusted prevalence of multimorbidity by districts in TCS

Getis-Ord General G (High/Low Clustering) test showed the similar results with the Global Moran's I test. The pattern of crude and age-adjusted prevalence of multimorbidity in provinces (crude: Observed General G: 0.06, z-score: 2.45, $p < 0.05$; age-adjusted: Observed General G: 0.06, z-score: 2.05, $p < 0.05$) and districts (crude: Observed General G: 0.001, z-score: 4.33, $p < 0.001$; Observed General G: 0.001, z-score: 6.21, $p < 0.001$) would be high-clustering.

Hotspot analysis (Getis-Ord G_i^*) was used to identify statistically significant areas with higher rates of multimorbidity, referred to as "hotspots". Hotspot is defined as a geographic area with a significantly higher prevalence of multimorbidity compared to its surroundings. Statistically significant hotspots were identified in Nonthaburi, Ang Thong, Sing Buri, Chai Nat and Nakhon Pathom provinces for both crude (Fig. 2A) and age-adjusted (Fig. 2B) multimorbidity prevalence. Statistically significant cold spots were identified in Krabi, Phangnga, Surat Thani, Ranong, Pattani, Yala and Narathiwat provinces, all of which are located in Southern Thailand. These provinces were consistently identified as cold spot regions in both crude (Fig. 2C) and age-adjusted analyses (Fig. 2D). Forty-eight districts were identified as both hotspots for crude and age-adjusted multimorbidity prevalence, 19 of which are located in Bangkok. Additionally, 30 districts were identified as cold spots.

The analysis of ordinal logistic regression

The population density (odd ratio, provincial level: OR:1.00, 95% CI: 1.00–1.01; district level: OR: 1.01, 95% CI: 1.00–1.01), the ageing index (provincial level: OR:1.03, 95% CI: 1.01–1.04; district level: OR: 1.01, 95% CI: 1.00–1.01), and average educational years (provincial level: OR:1.92, 95% CI: 1.07–3.48; district level: OR: 1.27, 95% CI: 1.02–2.26) were greater in hotspot places (see Table 2). However, in Supplementary Table 1, in crude multimorbidity prevalence, only the aging index in hot spots was associated with higher multimorbidity prevalence at the provincial level (OR: 1.02, 95% CI: 1.01–1.05) and the district level (OR: 1.03, 95% CI: 1.02–1.07). In addition, monthly average income per household (Baht) (OR:1.01, 95% CI: 1.00–1.03) would be greater in provinces (hot spots) of high age-adjusted multimorbidity prevalence (see Table 2).

Discussion

This study utilized data from the Thai Cohort Study (TCS) to explore the spatial variation of multimorbidity. The adjusted prevalence was found to be higher in Bangkok and metropolitan areas and lower in several southern provinces. Hotspots were mainly concentrated in Bangkok and its surrounding regions, whereas cold spots were predominantly located in the south.

We observed that multimorbidity prevalence was higher in areas with greater population density, higher household incomes, and longer average years of education. This finding suggests that more prosperous areas tend to have higher prevalence, which contrasts with some studies showing higher multimorbidity in socio-economically disadvantaged areas [30–32]. Typically, low socioeconomic status (SES) is associated with poor living conditions, environmental pollution, and limited access to healthcare [31–33]. However, in some low- and middle-income countries, such as Kenya and South Africa [34], higher SES is linked to higher multimorbidity rates due to better access to healthcare, sedentary lifestyles, stress, and polypharmacy [33, 34].

Regions with more medical resources may also have higher rates of diagnosis and reporting, leading to a higher observed prevalence due to more comprehensive case recording [1, 35, 36]. In Thailand, disparities in wealth and healthcare access, particularly between Bangkok and other regions, may contribute to these patterns. Wealthier regions, like Bangkok, benefit from better healthcare infrastructure and thus show higher reported rates, whereas underreporting may occur in less-resourced southern regions [1, 37].

Our study identified population density, aging index, and average years of education as the three key contextual factors associated with multimorbidity hotspots, with education showing the strongest effect based on odds ratio (OR) results. These findings underscore the need for tailored prevention and management strategies, particularly in under-resourced regions [38].

Strengthens and Limitations

This study is the first to apply spatial analysis to multimorbidity using data from the Thai Cohort Study. This innovative approach provides fresh perspectives and contributes to the literature on multimorbidity prevalence. Spatial analysis offers a geographic lens to reveal differences and patterns across regions, enhancing understanding of location-based factors and informing regional healthcare interventions [4, 6].

Nonetheless, the study has some limitations. First, although the composition of TCS participants is broadly like the general Thai population, there are still differences that may limit generalizability [4]. Second, data completeness varied across regions, with some areas having missed or incomplete information on certain diseases, affecting the comprehensiveness of the analysis [12, 14, 15]. Third, potential confounding factors such as environmental or socio-economic variables, could not be fully controlled, potentially influencing the findings [4, 6]. Furthermore, due to data availability, socio-demographic

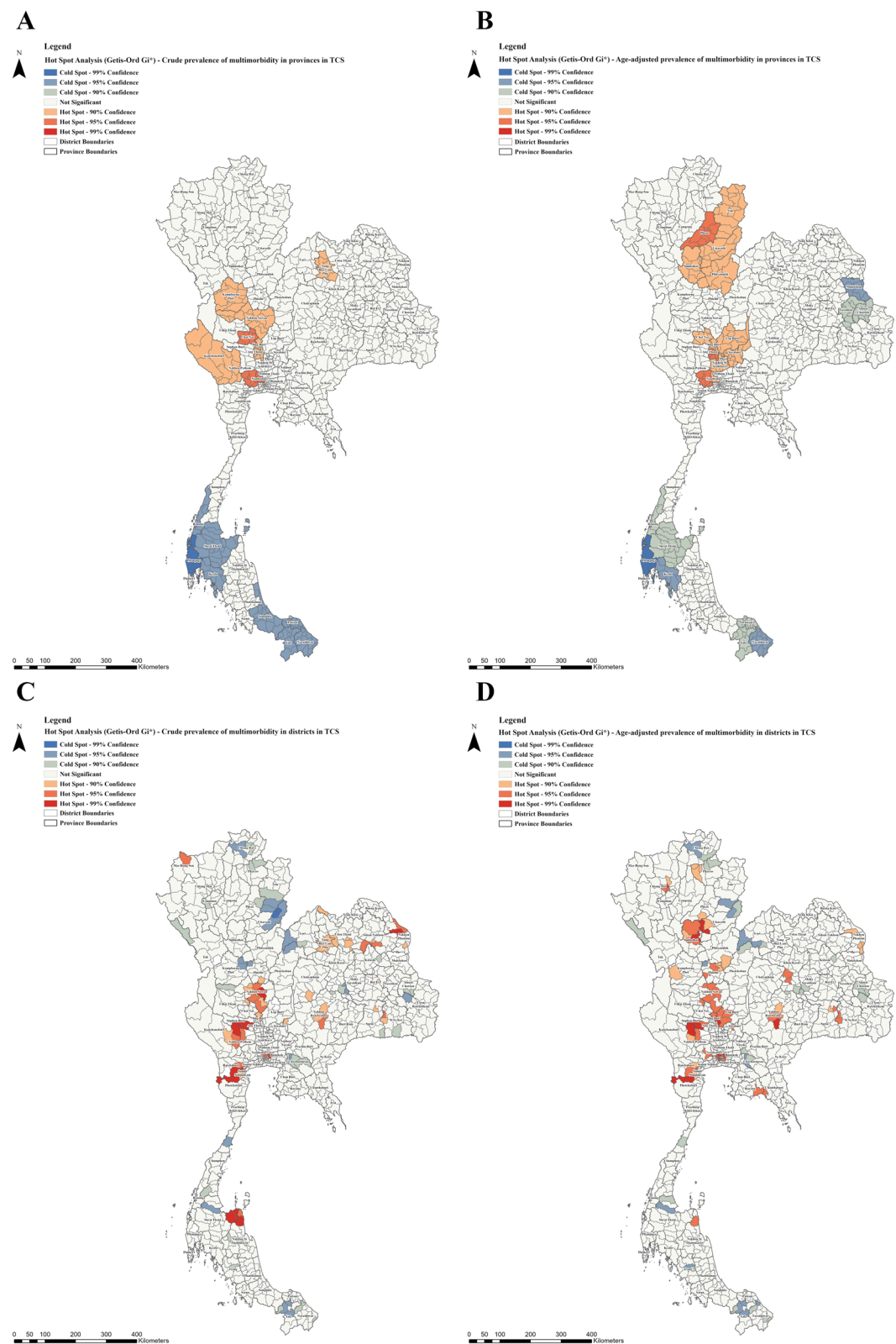


Fig. 2 The Hotspot analysis (Getis-Ord G_i^*) of multimorbidity prevalence in Thai Cohort Study (TCS) in 2013. Figure 2A The Hotspot analysis (Getis-Ord G_i^*) of crude prevalence by provinces in TCS; Fig. 2B The Hotspot analysis (Getis-Ord G_i^*) of age-adjusted prevalence by provinces in TCS; Fig. 2C The Hotspot analysis (Getis-Ord G_i^*) of crude prevalence by districts in TCS and Fig. 2D The Hotspot analysis (Getis-Ord G_i^*) of age-adjusted prevalence by districts in TCS

Table 2 Ordinal logistic regression of socio-demographic factors associated with age-adjusted multimorbidity prevalence in 2013

Contextual socio-demographic factors	Odd Ratio (OR*)	
	Age-adjusted Multimorbidity prevalence (%)	
	Provinces (95%CI**)	Districts (95%CI)
Population density (person/km ²)	1.00 (1.00–1.01)	1.01 (1.00–1.01)
Aging index***	1.03 (1.01–1.04)	1.01 (1.00–1.01)
Monthly average income per household (Baht)	1.01 (1.00–1.03)	NA
Average annual personal income (Baht)	1.00 (0.99–1.00)	1.00 (1.00–1.00)
Poverty line (expenditure, Baht)	1.00 (0.98–1.01)	NA
Average educational years	1.92 (1.07–3.48)	1.27 (1.02–2.26)
House density (n/km ²)	1.01 (0.99–1.03)	1.04 (0.97–1.06)

OR* odd ratio; 95% CI**: 95% confidential interval; **OR bolding**: The results of OR were statistical significance ($p < 0.05$); Aging index***: The aging index is an indicator that compares the substitution structure between the elderly population (aged 60 and above) and the child population (under 15 years old). NA Not available

information was analyzed at the provincial rather than district level, which may obscure finer-scale spatial patterns. The cross-sectional design also limits causal interpretation. Lastly, as multimorbidity diagnoses in the TCS were self-reported, the study may be subject to recall and reporting bias, which could impact data accuracy and the reliability of conclusions [12, 14, 15].

The future research

Although this study used data from 2013, the spatial patterns of multimorbidity and its associations with socio-demographic factors provide valuable insights into long-term trends. While specific health outcomes may have evolved, fundamental determinants such as population density, aging index, and education level, remain relevant [1, 4, 5]. Future research could employ hierarchical spatial models to examine cross-level interactions or variance components, offering a deeper understanding of multimorbidity distribution [6, 7]. Moreover, incorporating additional factors covering environmental exposures (e.g., air pollution), urbanization, lifestyle behaviours, and healthcare access (including the number, type, and quality of medical facilities across districts) could further enrich spatial analyses and inform targeted public health policies [4–7]. Additionally, the identification of geographic hotspots and cold spots of multimorbidity provides valuable evidence for policymakers to prioritize high-burden areas [1, 4, 15]. Such spatial insights can support more equitable distribution of healthcare resources and guide the development of region-specific prevention and management strategies [1, 4, 15].

Conclusion

The spatial analysis of multimorbidity prevalence in Thailand revealed that hotspots were concentrated in the central regions, including Bangkok, which are also

economically developed areas. In contrast, cold spots were found in the relatively underdeveloped southern region. Multimorbidity was associated with higher population density, a greater aging index, and longer average years of education. Therefore, its prevalence tends to be higher in developed regions than in less developed ones. Future studies should explore additional factors in spatial analyses to gain a more comprehensive understanding of the geographic characteristics of multimorbidity, leading to improved prevention and intervention strategies.

Abbreviations

TCS	Thai Cohort Study
OR	Odd ratio
LMICs	Low- and middle-income countries
NCDs	Non-communicable diseases
STOU	Sukhothai Thammathirat Open University
BMI	Body Mass index
WHO	World Health Organization
SES	Socio-economic status
CI	Confidential interval

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13690-025-01605-4>.

Additional file 1

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Authors' contributions

X.F. conceived the study, analyzed and interpreted the data and drafted the manuscript. X.F., N.B., H.S., T.T. and M.K. designed the study. S.S., A.S. and M.K. provided the dataset. X.F., H.S., N.B., T.T. and M.K. contributed to subsequent drafts and final editing.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

The studies involving humans were approved by the ethics committee of the Sukhothai Thammathirat Open University Research and Development Institute on October 22, 2005. Number: 0522/10. Date: October 22, 2005. For this sub-sample analysis, we also got approval from Human Research Ethics Committee of the Australian National University on January 25, 2022. Number: 2021/796. Date: January 25, 2022. The participants provided their written informed consent to participate in this study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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Supplementary Table 1. Ordinal logistic regression of socio-demographic factors associated with crude multimorbidity prevalence in 2013.

Contextual socio-demographic factors	Odd Ratio (OR*)	
	Crude	
	Multimorbidity prevalence (%)	
	Provinces	Districts
	(95%CI**)	(95%CI)
Population density (person/km ²)	1.00 (0.98-1.01)	1.02 (1.01-1.04)
Aging index***	1.02 (1.01-1.05)	1.03 (1.02-1.07)
Monthly average income per household (Baht)	1.01 (0.99-1.02)	NA
Average annual personal income (Baht)	1.00 (0.97-1.06)	1.01 (1.00-1.05)
Poverty line (expenditure, Baht)	0.45 (0.16-1.22)	NA
Average educational years	1.33 (0.73-2.46)	1.42 (1.27-1.58)
House density (n/km ²)	1.01 (0.98-1.03)	1.05 (0.93-1.08)

OR*: odd ratio;

95% CI**: 95% confidential interval;

OR **bolding**: The results of OR were statistical significance ($p < 0.05$);

Aging index***: The aging index is an indicator that compares the substitution structure between the elderly population (aged 60 and above) and the child population (under 15 years old).

NA: Not available.

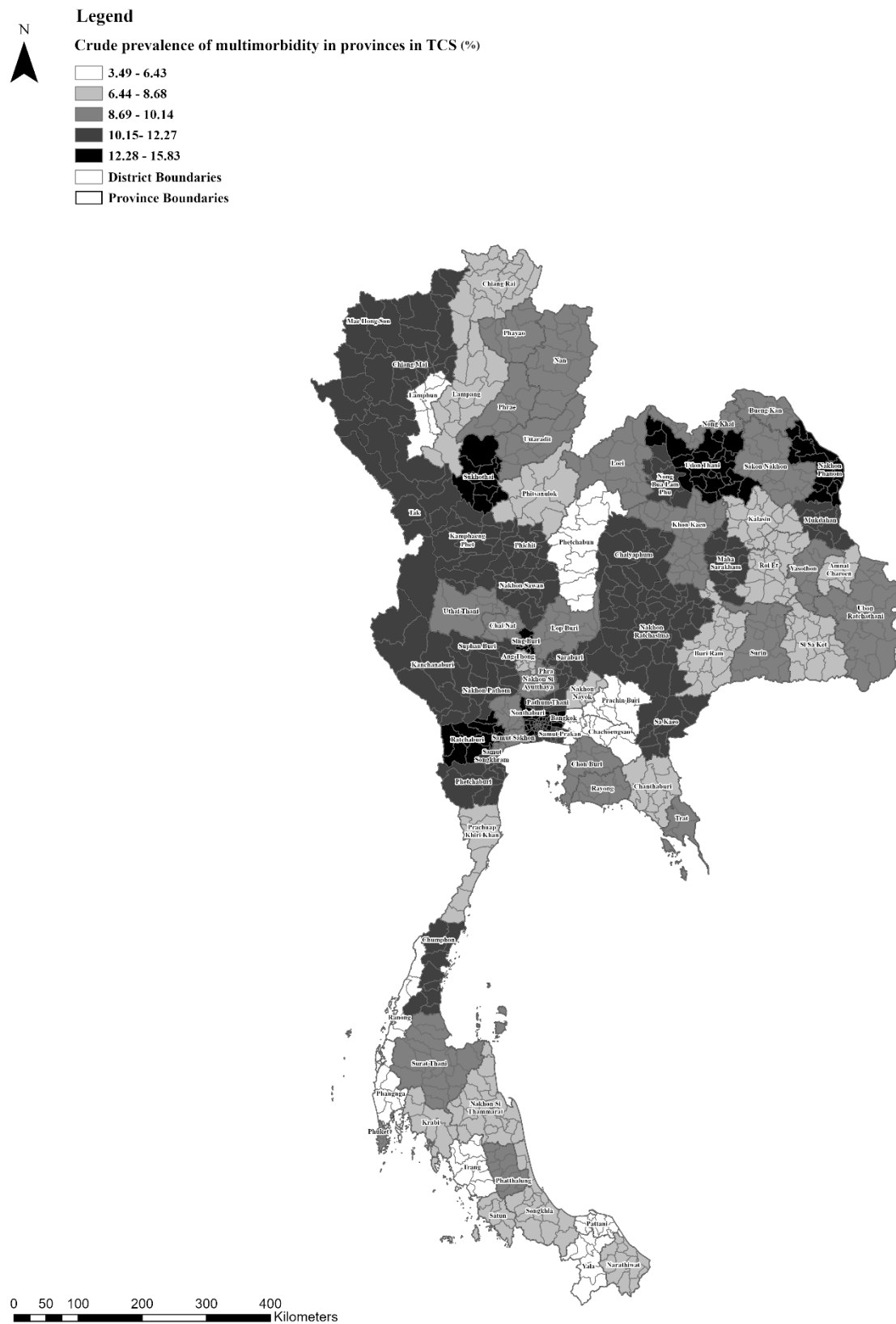


Fig. 1A Crude prevalence of multimorbidity by provinces in TCS

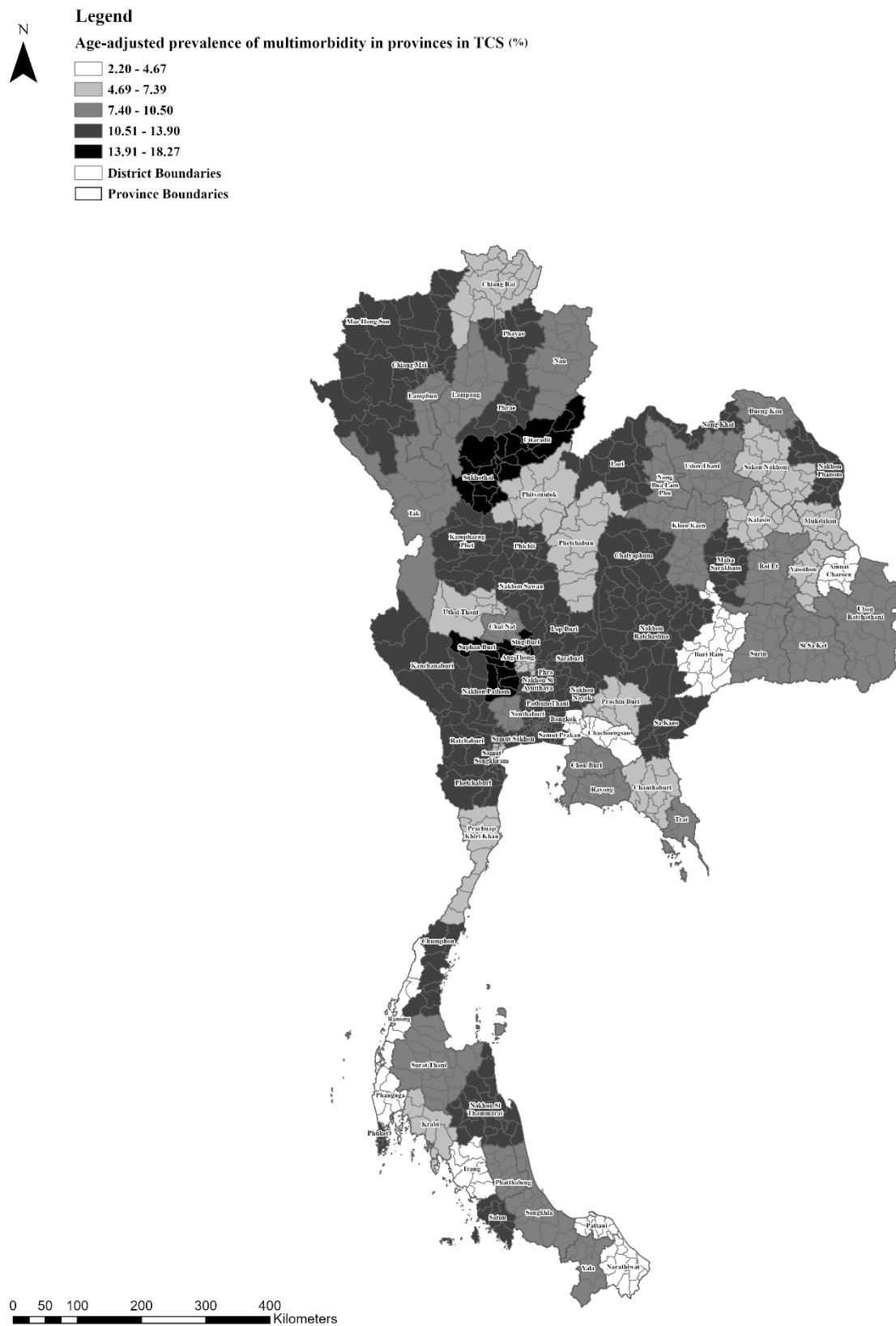


Fig. 1B Age-adjusted prevalence of multimorbidity by provinces in TCS



Fig. 1C Crude prevalence of multimorbidity by districts in TCS



Fig. 1D Age-adjusted prevalence of multimorbidity by districts in TCS

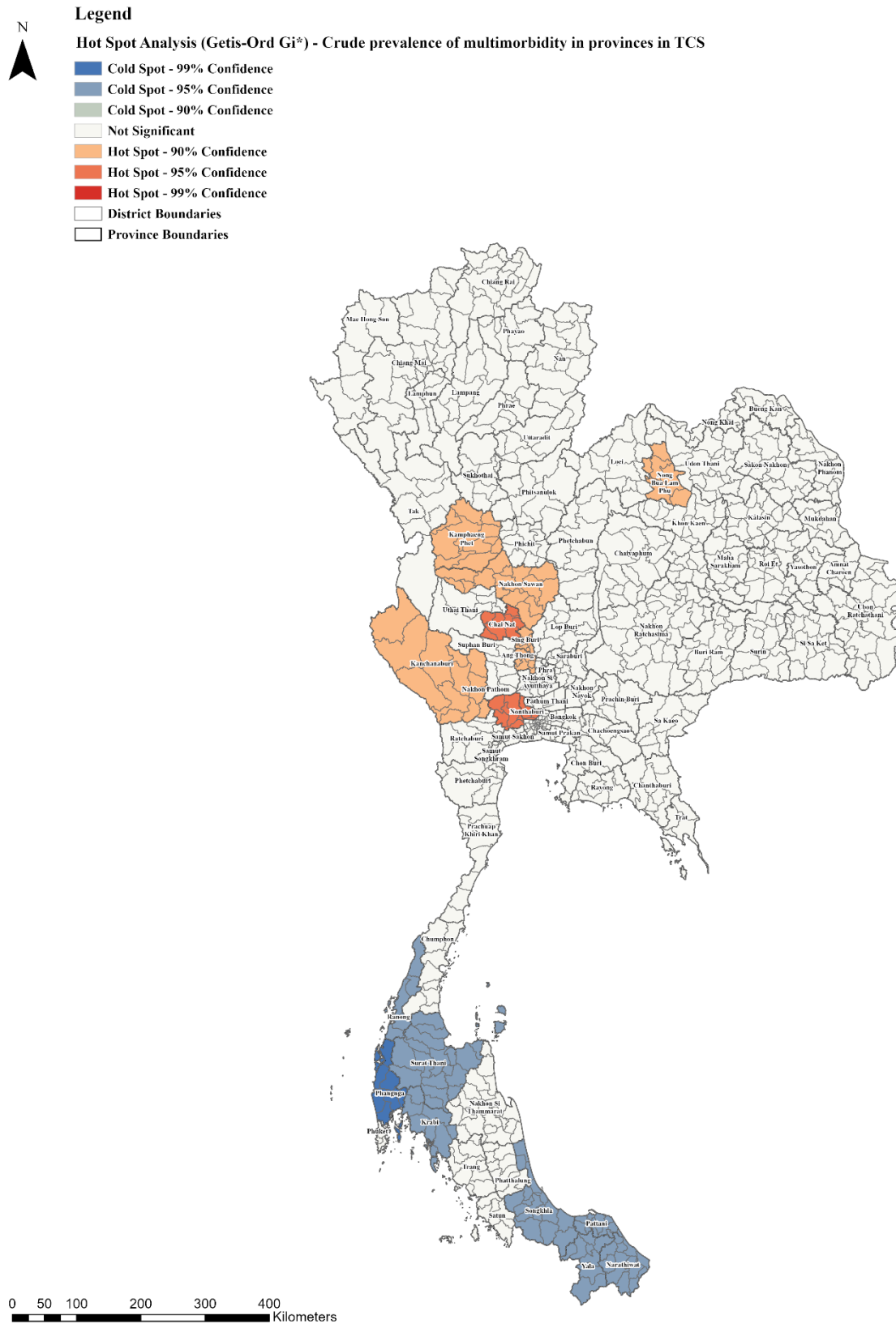


Fig. 2A The Hotspot analysis (Getis-Ord Gi*) of crude prevalence by provinces in TCS

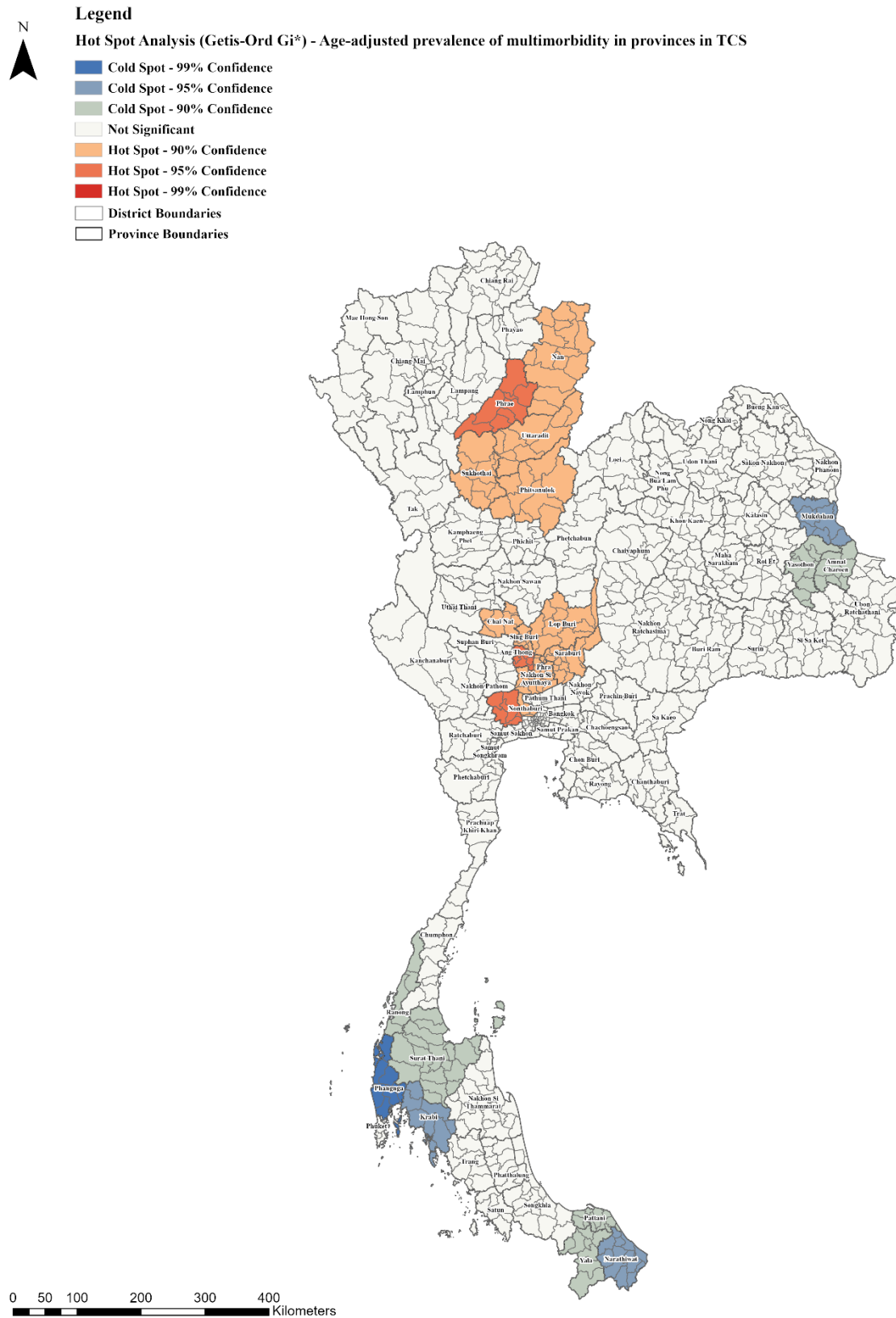


Fig. 2B The Hotspot analysis (Getis-Ord Gi*) of age-adjusted prevalence by provinces in TCS

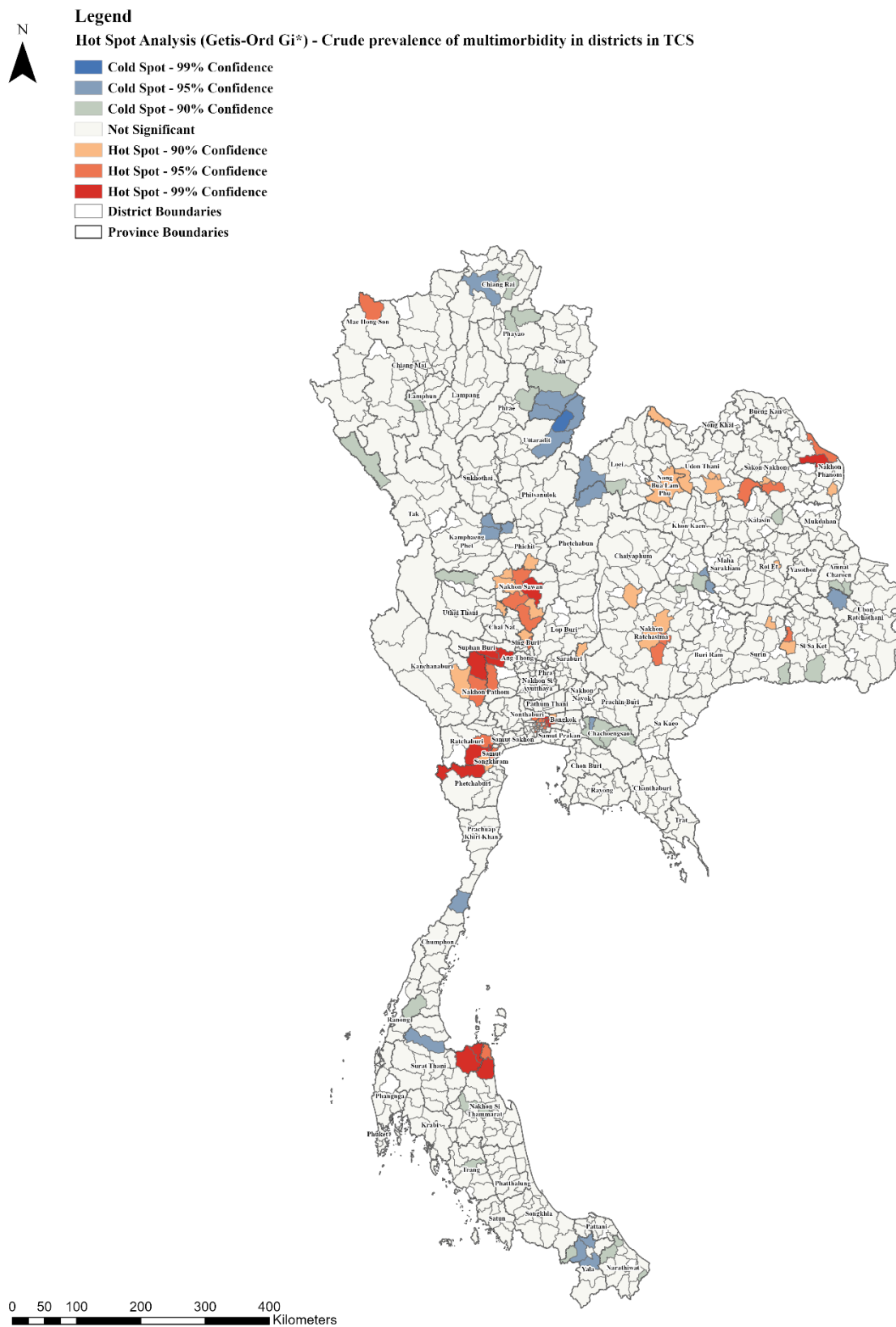


Fig. 2C The Hotspot analysis (Getis-Ord G_i^*) of crude prevalence by districts in TCS

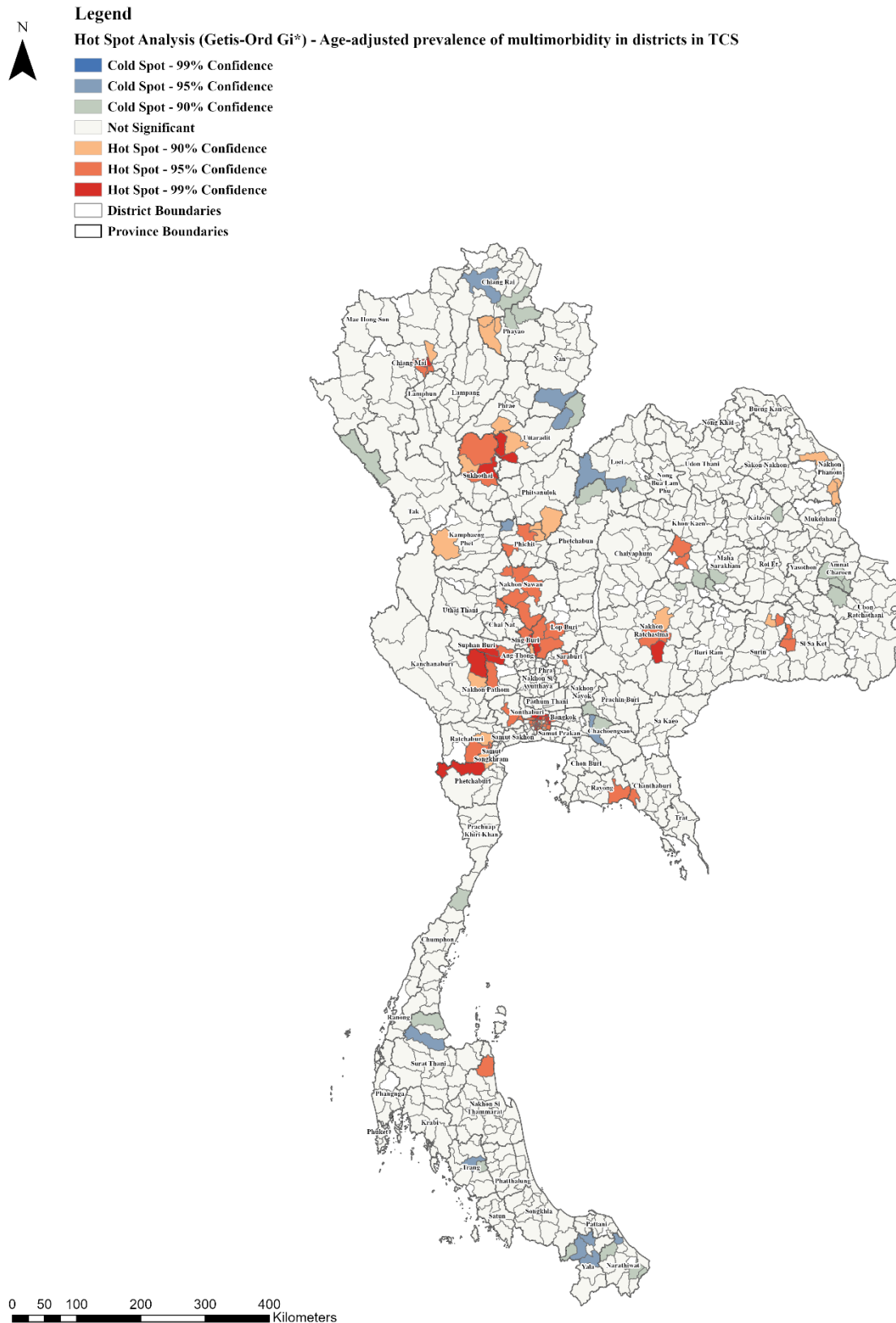


Fig. 2D The Hotspot analysis (Getis-Ord Gi*) of age-adjusted prevalence by districts in TCS

Chapter 8 Spatial analysis of multimorbidity using latent class analysis in Thailand

The previous chapter examined the spatial distribution of multimorbidity in Thailand and identified regional disparities and high prevalence “hotspot” areas. While these analyses highlighted geographical differences, they focused on the overall prevalence of multimorbidity without distinguishing between different patterns or combinations of chronic conditions. Such an approach does not capture the heterogeneity in multimorbidity, including which specific diseases tend to cluster together and whether these patterns differ across sociodemographic groups.

To address these limitations, this chapter employs latent class analysis (LCA) to identify potential subpopulations based on patterns of co-occurring chronic conditions. The latent classes are further described in terms of sociodemographic features and health behaviours. Additionally, spatial analysis is used to explore geographic disparities in the distribution of these latent classes, enabling the identification of high-prevalence areas and variations in disease clusters among different population groups. This approach supports the development of tailored, context-specific strategies for prevention and management of multimorbidity in Thailand.

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

Title: Spatial analysis of patterns of multimorbidity in the Thai Cohort Study using latent class analysis

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Spatial Analysis of patterns of Multimorbidity in the Thai Cohort Study Using Latent Class Analysis

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Abstract

Objective The study aims to determine patterns of multimorbidity among common non-communicable diseases (NCDs) in Thailand.

Study design Cross-sectional analysis.

Methods This study obtained self-reported data from 42,785 participants of the Thai Cohort Study (TCS) via mailed questionnaires. Information was collected on eight chronic conditions. Common multimorbidity (co-occurrence of two or more chronic conditions) patterns were identified and classified using latent class analysis (LCA). Multinomial models assessed associations with demographic and lifestyle factors, testing linear trends with P for trend (p-trend). The spatial analysis was used to identify potential clusters and high-risk areas of the age-adjusted prevalence of multimorbidity at the study area.

Results Four clusters were identified: “Relatively healthy” class (87.32%, reference), “Metabolic syndromes” class (10.20%), “Cardiometabolic disorders” class (1.53%), and “Multi-system conditions” class (0.95%) (percentages meaning proportion of this group). Older age and males were associated with an increased risk of multimorbidity. Attaining a university-level education was found to be a protective factor for in the classes of multimorbidity. Furthermore, engaging in housework appeared to be associated with a reduced risk of developing cardiometabolic conditions and multi-system disorders. Spatial analysis indicated that the high age-adjusted prevalence of “Cardiometabolic disorders” class tended to be clustered in central Thailand.

Conclusion Multimorbidity patterns were related to sociodemographic factors and lifestyles, and geographic characteristics. Future research should focus on classifying and comparing multimorbidity among different populations such as different age groups and genders in various locations. This would help in formulating targeted health policies and interventions to reduce their health burden.

Keywords Chronic conditions · Multimorbidity patterns · Latent class analysis · Spatial analysis · Thai Cohort study

1 Introduction

Multimorbidity, defined as having two or more chronic health conditions simultaneously, presents a significant health challenge, particularly as the global population ages [1, 2]. In low- and middle-income countries (LMICs) transitioning into aging societies, healthcare systems are often

challenged in addressing multimorbidity effectively, leading to higher mortality rates [3]. Socioeconomic disparities also contribute significantly to multimorbidity prevalence, as individuals with lower socioeconomic status (SES) face barriers in accessing healthy lifestyles, healthcare, and essential services, increasing their vulnerability to multimorbidity [4].

Thailand, a middle-income country in Southeast Asia, is undergoing a health transition from infectious disorders to non-communicable diseases (NCDs) and ageing patterns in Thailand [5]. With the prevalence of multimorbidity nearly tripling in the past decade from 10% to near 30% [6, 7], research on this topic remains in its early stages. Most analyses primarily focus on individual chronic conditions [5, 8]. Despite global studies highlighting prevalent multimorbidity patterns like cardiometabolic and mental-physical patterns

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[4, 8], research and discussions of multimorbidity in Thailand is also limited.

This study aims to utilize Latent class analysis (LCA), which identified subgroups based on patterns of chronic diseases [9, 10] to investigate the clustering of common chronic conditions in the large-scale Thai Cohort Study (TCS), based on their patterns of co-occurrence. The TCS sample is representative of the general Thai population, with demographic characteristics were similar to the national profile [5, 8]. Additionally, spatial analysis will be employed to explore the geographic distribution characteristics of these patterns. LCA will help to identify subgroups with specific chronic disease patterns, facilitating targeted managing of multimorbidity [9, 10], as observed in studies from Spain and South Africa [11, 12]. Furthermore, spatial analysis will also reveal geographic differences in chronic disease categories and help identify regional characteristics of chronic diseases in Thailand, identifying the disparities in chronic conditions clusters between high-prevalence areas and different backgrounds [13–15]. This will support the implementation of more targeted geographic prevention and more effective management strategies for these patterns of multimorbidity.

2 Methods

2.1 Study Samples

The Thai Cohort Study (TCS) is a nation-wide project launched in 2005 to investigate the health transition from infectious to non-communicable diseases (NCDs), comprising over 87,100 participants (15–87 years) recruited from Sukhothai Thammathirat Open University (STOU) who lived across Thailand [16, 17]. While participants reflected STOU's student body and the general Thai population in many aspects, they were younger, better educated, and more urban dwelling [18, 19].

2.2 Data Collection

Data were collected through three rounds of mailed questionnaires in 2005 (baseline), 2009 (midpoint), and 2013 (endpoint), with an average retention rate of approximately 70% at each follow-up visit. Surveys covered socio-demographics, lifestyle factors, and medical history [5, 16]. Our study focuses on data from the 2013 (endpoint) survey, comprising responses from 42,785 participants, representing a cross-sectional study design [8].

2.3 Multimorbidity Definition

Multimorbidity was defined as the presence of two or more chronic conditions simultaneously [5]. The 2013 survey

included questions about physician-diagnosed conditions, covering diabetes, hyperlipidaemia, hypertension, ischemic heart disease, cerebrovascular disease (stroke), kidney disease, and cancers (including liver cancer, lung cancer, stomach cancer, colon cancer, and breast cancer) [5, 8]. Participants also provided height and weight for calculating body mass index (BMI), with a BMI over 25 indicating obesity [8, 18]. Therefore, multimorbidity was identified when an individual reported two or more of these eight chronic conditions, including obesity.

2.4 The Associated Factors

Based on the TCS questionnaire and previous studies [5, 19, 20], relevant variables were divided into two broad categories: socio-demographic elements and health behaviour/personal lifestyle factors. Detailed classifications were listed in the Supplementary Table S1.

2.5 Statistical Analysis

Latent class analysis (LCA) is a valuable method for identifying subgroups within populations, discerning heterogeneity by assigning individuals to specific classes based on patterns of multiple chronic conditions [9, 10]. This study used LCA on the 42,785 participants in 2013 using Stata 17. Eight chronic conditions served as observed indicators [9–12]. The optimal number of latent classes was determined using robust indicators including Bayesian Information Criterion (BIC), adjusted Bayesian Information Criterion (aBIC), Akaike Information Criterion (AIC), and the Entropy Index [12]. Lower values of BIC, aBIC, and AIC indicated better model fit, while an Entropy Index value higher than 0.80 suggested highly discriminating latent classes [12]. Model fit was also confirmed by Vuong-Lo-Mendell-Rubin likelihood ratio test (LMR LR) and bootstrap-based likelihood ratio test (BLRT) ($p < 0.001$) [21]. Entropy Index value higher than 0.80 suggested highly discriminating latent classes [8]. Moreover, the average posterior probability indicated how accurately the model classifies individuals into the most likely category and the value above 0.70 meant accurate categorisation [21]. Once identifying the appropriate LCA model, each participant was assigned to the most likely class based on the largest “posterior probability”, which meant that the class they most likely belonged to [12, 21].

To handle missing values in chronic conditions (indicators) and other variables, we employed multiple imputation by chained equations (MICE), generating 10 imputed datasets to mitigate potential bias [9, 11]. Provincial-level addresses were also as a variable included in the imputations for subsequent spatial analysis (see Supplementary Table S2).

Adjusted multinomial logistic regression models (adjusted relative risk ratios, ARRRs) were used to assess the relationship between multimorbidity patterns and associated factors, with the “Relatively healthy” class as the reference. For each set of associations, we adjusted for other factors as confounders based on our descriptive data and observations other literature [5, 9, 20]. The results of the regression models in 10 imputed datasets were combined using Rubin's rules [21–23], and outcomes were presented with 95% confidence intervals (CI). Linear trend was evaluated using p-trend [5, 22], with statistical significance set at $p < 0.05$ [5, 22]. Stata 17 (College Station, TX: StataCorp LLC) conducted the analysis.

A sensitivity analysis applied the same models to a subset of participants ($n = 34,903$) with valid values for all variables. Results were compared with those from imputed datasets (see Supplementary Table S4).

2.6 Spatial Analysis

Spatial analysis is crucial for understanding the distribution and prevalence of chronic disease patterns in geographic regions, providing insights into the potential elements causing these patterns [13–15]. Spatial units were obtained from the Human Data Exchange-Thailand, delineating subnational administrative boundaries across Thailand's 76 provinces, with Bangkok as a special administrative area [24]. It means that the province was the unit of analysis. Regions with fewer than six participants were excluded from prevalence analyses to ensure analytical accuracy [25, 26].

Age-standardised prevalence rates of multimorbidity were computed for each province in Thailand to remove the effects of the age structure of the population and to reflect more accurately the burden of disease [13, 25, 26]. We computed the prevalence for various latent classes of chronic diseases across each province in Thailand using data from the TCS. The results of the proportion models in 10 imputed datasets were combined using Rubin's rules [21–23]. Then we got the crude prevalence of each latent classes in each province in which TCS members were living. To obtain age-adjusted prevalence, actual population proportions in each age group provided by the Thai government website (National Statistics Office) [27] were multiplied with the crude latent class prevalences in corresponding age groups from the TCS data [13, 26, 28]. These prevalences were mapped using ArcGIS Pro 2.6 desktop (ESRI, Redlands, CA).

Spatial Autocorrelation (Global Moran's I) and High/Low Clustering (Getis-Ord General G) tests examined clustering and high/low clustering of age-adjusted prevalence of the latent classes of chronic conditions (multimorbidity patterns). Hotspot analysis using Getis-Ord Gi* identified statistically significant areas of high and low prevalence of multimorbidity patterns [25, 26, 28]. Contiguity edges

corners technique conceptualized spatial connections, with row standardization used to generate proportional weights and mitigate neighbour count variations [25, 26, 28].

3 Results

3.1 The Characteristics of TCS Participants

This study comprised 42,785 individuals, as detailed in Table 1, outlining the characteristics of the 2013 Thai cohort study. The female participants in TCS outnumbered males, accounting for 54.8% compared to 45.2%. Moreover, a larger percentage cohabitated with partners (64.0%) rather than being single. In terms of geography, the eastern region had the fewest participants (8.0%), and 34.6% had moved from urban to rural areas during childhood. Women had higher university-level education rates (81.8%) compared to men (77.3%), with 79.7% overall. Additionally, 40.4% reported personal salaries exceeding 20,000 Baht per month (The average level of personal monthly income was around 8,700 baht in Thailand in 2013 [16, 19, 20]), and 69.2% lived in households with incomes surpassing 20,000 Baht (The average level of personal monthly income was around 24,800 baht in Thailand in 2013 [16, 19, 20]).

3.2 The Prevalence of the Chronic Conditions and Multimorbidity in the Thai Cohort Study (TCS)

Figure 1 showed the prevalence of the chronic conditions measured in the Thai Cohort Study. Among these conditions, obesity has the highest prevalence at around 28.48%, followed by hyperlipidaemia at 13.23% and hypertension at 7.17%. The least prevalent disease is ischaemic heart disease (around 0.30%). Moreover, the prevalence of multimorbidity was 10.29%.

3.3 Four Latent Classes in the Eight Chronic Conditions (the patterns of multimorbidity)

Supplementary Table S3 compared fit statistics for models with one to six classes, indicating that the four-class model had the lowest BIC (358,805.60), adjusted BIC (aBIC, 358,407.51) and relatively highest entropy value (0.94). Moreover, both LMR LR and BLRT were less than 0.0001. As for the average posterior probability, Class 1 was 0.65, Class 2 was 0.86, Class 3 was 0.70 and Class 4 was 0.78. Thus, we selected the four-class model for its optimal balance of complexity and fit. As for the class names, we named the classes after the diseases that had the highest probability of being in that class, or significant clinical categories. Supplementary Figure S1 displayed four chronic conditions

Table 1 The characteristics of the participants in 2013 Thai Cohort Study (TCS)

Factors	Numbers (n (%))			
	Total	Male	Female	Difference p-value
Participants	42,785 (100%)	19,330 (45.2%)	23,455 (54.8%)	
Age (years) means (SD)	40.50 (8.5)	42.3 (8.9)	39.0 (7.8)	p < 0.001
Age groups (years)				p < 0.001
≤ 39	21,938 (51.3%)	8251 (42.7%)	13,687 (58.4%)	
40–59	19,876 (46.5%)	10,371 (53.7%)	9505 (40.5%)	
≥ 60	971 (2.3%)	708 (3.7%)	263 (1.1%)	p < 0.001
Marital status				
Living with partner	26,987 (64.0%)	13,668 (71.9%)	13,319 (57.5%)	
Single	15,167 (36.0%)	5335 (28.1%)	9832 (42.5%)	p < 0.001
Geographic regions				
Bangkok	6742 (15.8%)	2612 (13.5%)	4130 (17.6%)	
Central	9684 (22.6%)	4066 (21%)	5618 (24%)	
North	8592 (20.1%)	4134 (21.4%)	4458 (19%)	
Northeast	8965 (21%)	4714 (24.4%)	4251 (18.1%)	
East	3431 (8.0%)	1512 (7.8%)	1919 (8.2%)	
South	5371 (12.6%)	2292 (11.9%)	3079 (13.1%)	p < 0.001
Life course residence*				
Rural-rural (RR)	2641 (18.9%)	1214 (20.6%)	1217 (17.4%)	
Rural-urban (RU)	3971 (28.6%)	1921 (27.8%)	2050 (27.3%)	
Urban-rural (UR)	4807 (34.6%)	2320 (33.6%)	2487 (35.5%)	
Urban-urban (UU)	2489 (17.9%)	1244 (18.0%)	1245 (17.8%)	p < 0.001
Socioeconomic status				
Education level				
Junior school	372 (0.9%)	252 (1%)	120 (0.5%)	
High school	5436 (12.8%)	2875 (15%)	2561 (11%)	
Diploma	2814 (6.6%)	1237 (6.4%)	1577 (6.8%)	
University	33,940 (79.7%)	14,855 (77.3%)	19,085 (81.8%)	p < 0.001
Monthly personal income (Baht)#				
≤ 7000	4080 (9.6%)	1688 (8.8%)	2392 (10.3%)	
7001–10 000	5320 (12.6%)	1860 (9.7%)	3460 (14.9%)	
10 001–20 000	15,834 (37.4%)	6366 (33.3%)	9468 (40.8%)	
≥ 20 001	17,087 (40.4%)	9217 (48.2%)	7870 (33.9%)	p < 0.001
Monthly household income (Baht)##				
≤ 7000	2608 (6.2%)	1327 (7.0%)	1281 (5.5%)	
7001–10 000	2670 (6.3%)	1143 (6.0%)	1527 (6.6%)	
10 001–20 000	7748 (18.3%)	3080 (16.1%)	4668 (20.1%)	
≥ 20 001	29,271 (69.2%)	13,529 (70.9%)	15,742 (67.8%)	p < 0.001

Life course residence*: Urbanization status was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) [16, 19, 20]. Monthly personal income (Baht)#: The average level of personal monthly income was around 8,700 Baht in Thailand in 2013 [16, 19, 20]. Monthly household income (Baht)##: The average level of personal monthly income was around 24,800 Baht in Thailand in 2013 [16, 19, 20]. The analyses were performed before multiple imputation procedure

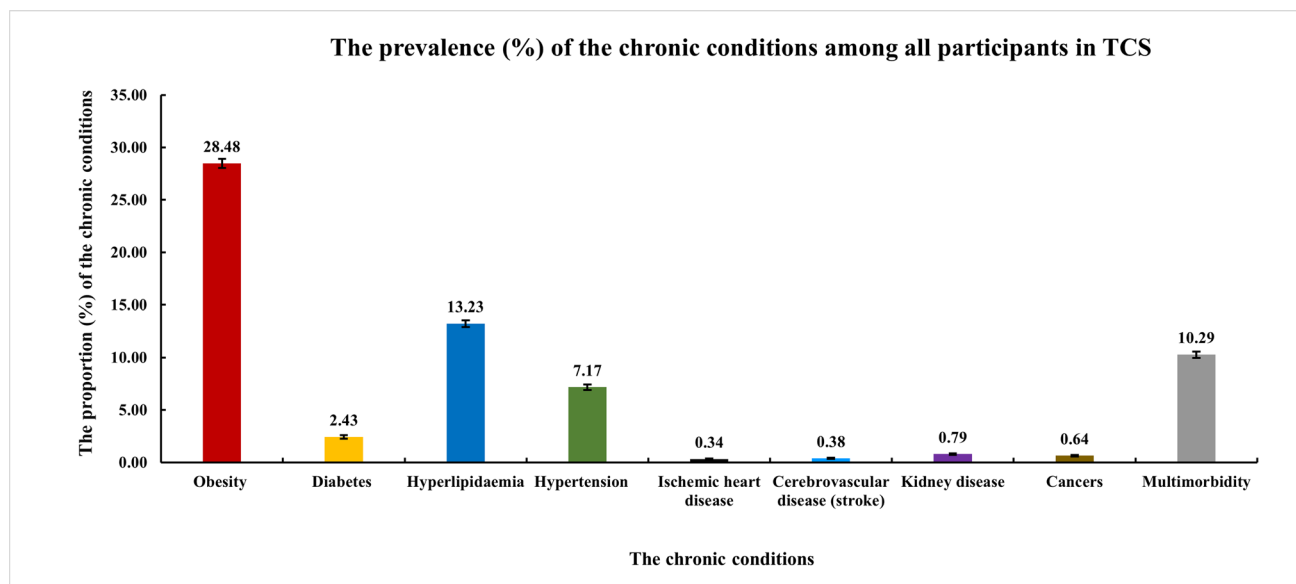


Fig. 1 The prevalence of chronic conditions among all participants in Thai Cohort Study (TCS). The analyses were performed before multiple imputation procedure

classes and their respective membership probabilities, namely “Relatively healthy” class, “Metabolic syndromes” class, “Cardiometabolic disorders” class, and “Multi-system conditions” class. Most of the population was relatively healthy (87.32%), with metabolic syndrome being the most common pattern of multimorbidity, accounting for 10.20%. “Cardiometabolic disorders” class’s proportion was 1.53% and the “Multi-system conditions” class was 0.95%.

In “Relatively healthy” class, the probabilities of all diseases were relatively low (see Supplementary Figure S2). The probabilities of obesity, hyperlipidaemia, and hypertension in the “Metabolic syndromes” class were relatively high, at 44.40%, 54.73%, and 53.65%, respectively. The probability of obesity was highest in the “Cardiometabolic disorders” class, at 85.38%. Finally, the “Multi-system conditions” class showed high probabilities for most diseases except cancers (8.42%).

3.4 The Association of Latent Classes/ Multimorbidity Patterns and Related Factors

Table 2 presented adjusted relative risk ratios (ARRRs), measuring associations between various exposure variables, and risk of being placed in a particular multimorbidity class, with the “Relatively healthy” group as reference, among all 2013 TCS participants. Older age groups (40–59 years and over 60 years) showed increased likelihood of multimorbidity patterns (all ARRR > 1.00 in three classes, $p < 0.05$; p -trend = 0.0314 for “Metabolic syndromes”, 0.0354 for “Cardiometabolic disorders”, and 0.0445 for “Multi-system conditions”). Females

exhibited decreased risk across all patterns (“Metabolic syndromes”: ARRR = 0.70, 95%CI: 0.60–0.81; “Cardiometabolic disorders”: ARRR = 0.43, 95%CI: 0.38–0.48; “Multi-system conditions”: ARRR = 0.28, 95%CI: 0.17–0.47). Residence in northeast and south Thailand was protective against “Metabolic syndromes” and “Cardiometabolic disorders” ($p < 0.05$). University education showed protective effects across all classes (“Metabolic syndromes”: ARRR = 0.63, 95%CI: 0.49–0.87; “Cardiometabolic disorders”: ARRR = 0.57, 95%CI: 0.30–0.75; “Multi-system conditions”: ARRR = 0.74, 95%CI: 0.36–0.96). Increased housework frequency was negatively associated with “Cardiometabolic disorders” class and “Multi-system conditions” class. Smoking increased risk for metabolic syndromes (ARRR = 1.22, 95%CI: 1.10–1.48) and cardiometabolic disorders (ARRR = 1.74, 95%CI: 1.23–2.90). Regarding alcohol consumption, ex-drinkers had higher likelihood of metabolic syndromes (ARRR = 1.28, 95%CI: 1.14–1.56) and cardiometabolic disorders (ARRR = 1.11, 95%CI: 1.01–1.33) compared to non-drinkers.

3.5 The Sensitivity Analysis

The regression models were run again using complete case analysis ($n = 34,903$) (see Supplementary Table S4). In general, the results were similar to those obtained using multiple imputation. However, there were some small differences between them. For example, high-frequency weekly exercise (over 15 sessions) was associated with a reduced risk

Table 2 The association between latent classes of multimorbidity and related factors in all individuals in TCS

Factors	“Relatively Healthy” class (Reference class)	“Metabolic syndromes” class		“Cardiometabolic disorders” class		“Multi-system conditions” class	
		ARRR* (95% CI)		ARRR* (95% CI)		ARRR* (95% CI)	
Socio-Demographics							
Gender (reference: male)							
Female	1.00	0.70	(0.60, 0.81)	0.53	(0.38, 0.65)	0.83	(0.58, 0.96)
Age (years) (reference: ≤ 39 years)							
40–59 years	1.00	4.04	(2.52, 5.53)	6.97	(1.69, 2.43)	2.97	(2.02, 7.59)
≥ 60 years	1.00	12.98	(8.38, 15.58)	23.06	(13.63, 37.57)	11.22	(4.98, 29.01)
p-trend		0.0314		0.0354		0.0445	
Geographic regions (reference: Bangkok)							
Central	1.00	0.82	(0.66, 1.01)	0.82	(0.66, 1.02)	0.76	(0.40, 1.41)
North	1.00	1.19	(0.96, 1.48)	1.09	(0.85, 1.39)	0.86	(0.43, 1.74)
Northeast	1.00	0.78	(0.64, 0.88)	0.68	(0.53, 0.86)	0.63	(0.32, 2.82)
East	1.00	0.89	(0.67, 1.19)	0.97	(0.71, 1.33)	0.54	(0.17, 3.65)
South	1.00	0.66	(0.50, 0.86)	0.74	(0.56, 0.98)	0.71	(0.32, 2.59)
Educational level (reference: Junior school)							
High school	1.00	0.85	(0.45, 1.61)	0.41	(0.11, 1.04)	0.89	(0.18, 3.10)
Diploma	1.00	0.58	(0.29, 1.15)	0.74	(0.28, 1.23)	0.93	(0.41, 1.63)
University	1.00	0.63	(0.49, 0.87)	0.57	(0.30, 0.75)	0.74	(0.36, 0.96)
p-trend		0.0897		0.4331		0.1295	
Health behaviours/Personal lifestyles							
Excise							
Housework (reference: Never)							
1–3 times/month	1.00	1.03	(0.72, 1.30)	0.97	(0.85, 1.11)	0.56	(0.32, 0.88)
Once or twice/week	1.00	0.99	(0.70, 1.26)	0.90	(0.77, 1.14)	0.48	(0.17, 0.65)
3–4 times/week	1.00	0.89	(0.64, 1.16)	0.79	(0.71, 0.89)	0.51	(0.21, 0.85)
Every day or more	1.00	1.01	(0.79, 1.27)	0.71	(0.60, 0.84)	0.55	(0.49, 0.67)
p-trend		0.5665		0.0025		0.1888	
Smoking and drinking status							
Smoking (reference: Non-current smoker)							
Current smoker	1.00	1.22	(1.01, 1.48)	1.01	(0.86, 1.19)	1.74	(1.23, 2.90)
Drinking (reference: Never)							
Ex-drinker	1.00	1.28	(1.14, 1.56)	1.11	(1.01, 1.33)	1.14	(0.67, 1.83)
Occasional or social	1.00	0.89	(0.76, 1.04)	0.80	(0.61, 1.23)	0.62	(0.33, 1.48)
Current regular	1.00	0.97	(0.48, 1.60)	1.21	(0.86, 1.67)	0.88	(0.34, 1.56)
p-trend		0.3311		0.7228		0.3994	

ARRR*: Adjusted Relative risk ratios from multinomial logistic regression models of latent class controlling for socio-demographic factors, and personal lifestyles

95% CI: 95% confidential intervals

ARRR bolding: The results of ARRR were statistical significance ($p < 0.05$)

p-trend bolding: The results of p-trend were statistical significance (p for trend < 0.05)

Models were run in 10 imputed datasets and results combined using Rubin's rules

of the “metabolic syndrome” class (ARRR = 0.89, 95%CI: 0.75–0.97) when using the complete case, but this association was not significant when analysing imputed data.

3.6 The Spatial Analysis of Age-Adjusted Prevalence of Latent Classes/Multimorbidity Patterns

Figure 2 depicted the age-adjusted prevalence of latent classes. Phangnga Province had the highest percentage of “Relatively healthy” individuals, approximately 65.6%,

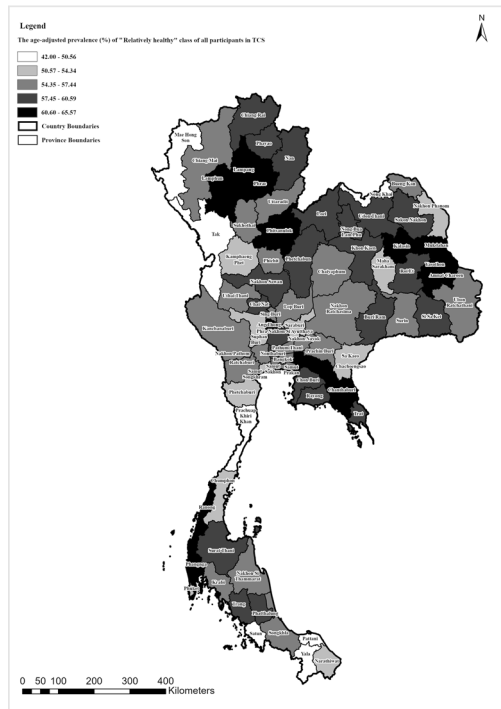
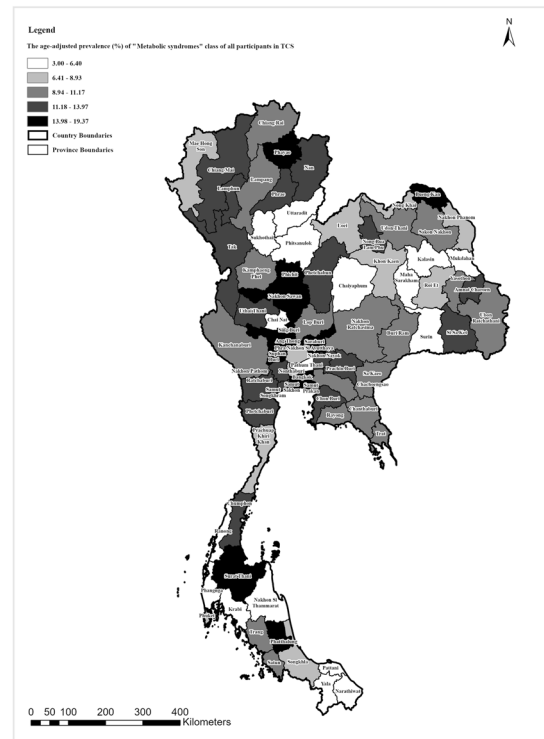
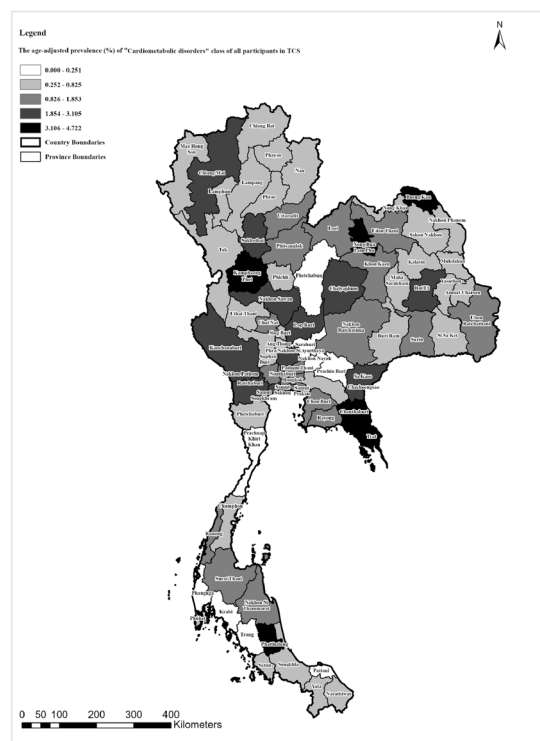
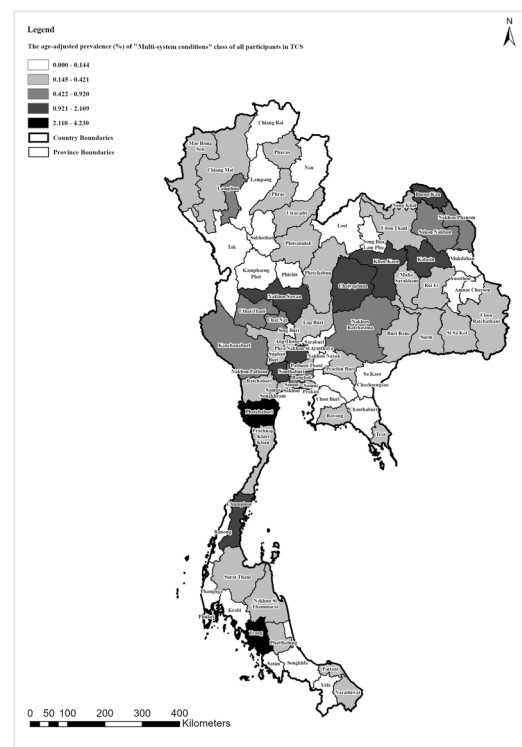
A: “Relative healthy” class**B: “Metabolic syndrome” class****C: “Cardiometabolic disorders” class****D: “Multi-system conditions” class**

Fig. 2 The age-adjusted prevalence (%) of 4 latent classes in all participants in TCS. Models were run in 10 imputed datasets and results combined using Rubin’s rules

while Phichit Province exhibited the highest prevalence of “Metabolic syndromes” at around 20%. The highest prevalence of “Cardiometabolic disorders” was located in central provinces in Thailand (central regions), at 1.47%. Additionally, there were 20 provinces that showed zero age-adjusted prevalence of “Multi-system conditions”.

3.7 The Spatial Analysis

Spatial autocorrelation of multimorbidity by provinces was assessed using the Global Moran's I test, indicating significant clustering in two latent classes (“Relatively healthy” class: Moran's Index: 0.227048, p-value: 0.001570; “Cardiometabolic disorders” class: Moran's Index: 0.183414, p-value: 0.008475). However, no significant clustering was observed in the “Metabolic syndromes” class (Moran's Index: 0.092943, p-value: 0.143875) or the “Multi-system conditions” class (Moran's Index: −0.042808, p-value: 0.684156). Similarly, the Getis-Ord General G test corroborated these findings, with significant clustering in the “Relatively healthy” class (Observed General G: 0.013202, z-score: 2.262904, p-value: 0.023642) and suggestive clustering in the “Cardiometabolic disorders” class (Observed General G: 0.014257, z-score: 1.840988, p-value: 0.065623), but no significant clustering in the other classes ($p > 0.10$).

The hotspot analysis (Getis-Ord G_i^*) results, as depicted in Fig. 3, in the “Relatively healthy” class, hotspot regions were identified in Phayao, Mukdahan, Yasothorn, Ubon Ratchathani and Amnat Charoen Provinces. For the “Cardiometabolic disorders” class, most hotspot areas (Nakhon Pathom, Chanthaburi and Trat Provinces) were concentrated in the Central and Eastern part of Thailand. Moreover, in the cluster and outlier analysis (Anselin Local Moran's I) (see Supplementary Figure S3), in “Cardiometabolic disorders” class, Nakhon Pathom and Trat Provinces presented High-High clustered values.

4 Discussion

This study aimed to characterize multimorbidity patterns in the Thai Cohort Study (TCS) of 2013 using latent class analysis (LCA), identifying four distinct latent classes (“Relatively healthy (reference),” “Metabolic syndromes,” “Cardiometabolic disorders,” and “Multi-system conditions”) based on eight chronic conditions. These clusters were positively associated with age across three classes, smoking in the “Metabolic syndromes” and “Multi-system conditions” classes, and ex-drinking in the “Metabolic syndromes” and “Cardiometabolic disorders” classes. Conversely, they were negatively associated with females and university-level education across all three classes, living in the northeast and south of Thailand in the “Metabolic syndromes” class and

“Cardiometabolic disorders” classes, and engaging in housework in the “Cardiometabolic disorders” and “Multi-system conditions” classes.

4.1 The clusters of chronic conditions in LCA

In our study, the majority of the sample fell into the “Relatively healthy” class, consistent with findings from previous studies using LCA [9, 29]. The other three latent classes (“Metabolic syndromes”, “Cardiometabolic disorders”, and “Multi-system conditions”) also align with common disease classifications observed in prior research [9, 30–32]. For instance, the “Metabolic syndromes” class predominantly comprised obesity, hypertension, and hyperlipidaemia,³⁰ resembling patterns found in one study in China [33]. The “Cardiometabolic disorders” class identified in other studies [31] as a common pattern of multimorbidity, where prevalent diseases included diabetes, hypertension, heart disease, hyperlipidaemia, and obesity [31]. Similarly, the “Multi-system conditions” class exhibited a combination of various chronic diseases, akin to another Chinese latent class analysis of multimorbidity pattern study [32].

4.2 Age and Gender Differences

In this study, age emerged as a consistent risk factor across all three multimorbidity patterns, aligning with previous research [12, 34]. Men exhibited a higher likelihood of being classified into these patterns, possibly due to elevated cardiovascular and metabolic disease risk factors, such as smoking and alcohol consumption [12, 35].

4.3 The Socioeconomic Factors

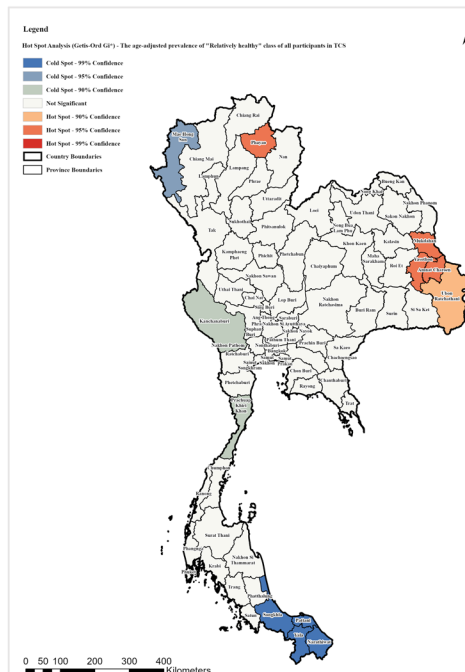
Higher education levels appeared to reduce the risk of developing these disorders, consistent with findings from a systematic review on education level and multimorbidity in Southeast Asia [36]. This association may stem from increased socioeconomic status and health literacy among more educated individuals, promoting healthier lifestyles and mitigating multimorbidity risk [36, 37].

4.4 The Lifestyle Factors and Health Risks

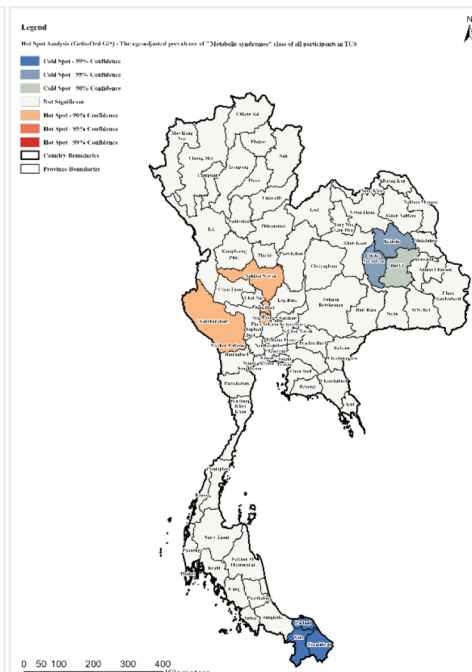
Housework, as a form of exercise, may reduce the risk of cardiometabolic and multi-system conditions by improving cardiovascular function, lowering blood pressure, controlling blood lipids, and managing weight [38, 39]. However, drinking and smoking are significant risk factors for multimorbidity [40]. Interestingly, ex-drinkers had a higher likelihood of developing these multimorbidity patterns compared

Fig. 3 Hot Spot analysis (Getis-Ord Gi*)—The age-adjusted prevalence (%) of 4 latent classes in all participants in TCS. Models were run in 10 imputed datasets and results combined using Rubin's rules

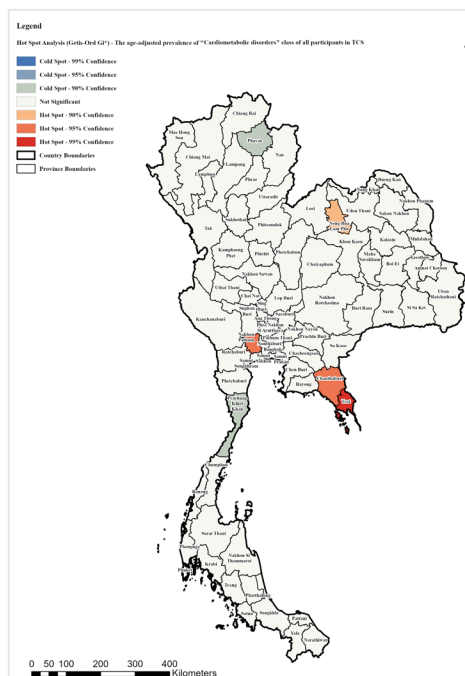
A: “Relative healthy” class



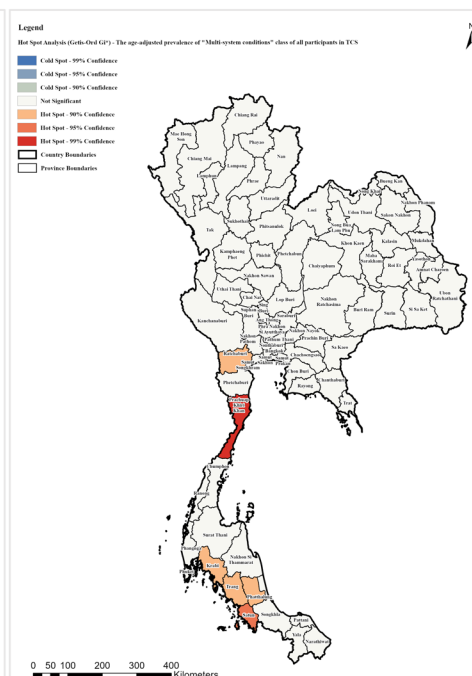
B: “Metabolic syndrome” class



C: “Cardiometabolic disorders” class



D: “Multi-system conditions” class



to non-drinkers, consistent with findings from other studies

[40]. This could be attributed to the health-damaging effects of alcohol, leading many former drinkers to quit upon realizing its adverse impact on their health [40, 41].

4.5 Geographic Distribution and Spatial Analysis

It was noticed that the prevalence of latent classes of diseases in the capital region was relatively higher, which may be related to the socio-economic development level of the region. Bangkok (the capital in Thailand) is more developed in terms of social and economic conditions than other regions in Thailand, people living in the city may have less healthy lifestyles [42, 43]. Spatial analysis within the Thai Cohort Study (TCS) revealed distinct geographical clustering of high age-adjusted prevalence of cardiometabolic disorders in the central region of Thailand, known for its advanced development and higher population density [14, 15, 42]. This observation suggests that regions with higher development levels exhibit a higher prevalence of cardiometabolic multimorbidity patterns, potentially due to increased stress levels, reduced physical activity [38, 39, 44], and dietary habits rich in oils and fats, all significant risk factors associated with cardiometabolic diseases [45]. Targeted interventions aimed at promoting healthier lifestyles, reducing stress levels, and improving dietary habits in developed regions are crucial for mitigating the burden of cardiometabolic conditions and enhancing overall population health [46].

4.6 Strengths, Limitations and Future Research

4.6.1 Strengths

One major strength of this study was the use of the extensive set of variables in the TCS database for investigating multimorbidity patterns via latent class analysis, complemented by spatial analysis to understand geographical distribution characteristics. Despite relying on self-reporting methods for disease data collection, previous research by Papier et al. [17] demonstrated high consistency with clinical data, supporting the reliability of our findings. The other strength was that we used multiple imputation in our study. Multiple imputation was used to address missing data, ensuring robust and reliable analysis, particularly for chronic conditions and their associated factors. By leveraging all available information, this method minimizes bias, enhances the precision of estimates, and provides a more comprehensive representation of the population and relationships under study. This approach strengthens the validity and generalizability of the findings, offering a clearer understanding of the associations between chronic conditions and their contributing factors [21].

4.7 Limitations

However, several limitations exist. The cross-sectional design precludes establishing causal relationships [8].

Moreover, although our data came from the cohort study which provided longitudinal data, the relatively short follow-up period of only 8 years and the relatively young age of the population limit our ability to accurately measure the longitudinal incidence of multimorbidity [8]. Data collection occurred in 2013, potentially limiting the current relevance of findings [8, 20]. Participant demographics skewed towards more educated individuals compared to the general Thai population [16]. The range and number of chronic diseases studied may not be exhaustive, with psychological illnesses omitted [8]. Misclassification into latent classes would be possible [9, 11], and multiple imputations may introduce bias, though sensitivity analysis confirmed robustness [9, 22, 23].

4.8 Future Research

Future studies could employ longitudinal designs which would be valuable for tracking the progression and evolution of multimorbidity patterns over time, providing deeper insights into causal relationships and the dynamic interactions between conditions and risk factors [47, 48]. The further studies could also consider longer follow-up periods, make participants more representative of the overall Thai population, include a wider range of chronic conditions, adopt in more detail in spatial analyses, to provide a more comprehensive understanding of multimorbidity patterns and better support geographically targeted management [31, 34]. Exploring alternative classification methods [4, 47, 48] and comparing multimorbidity across diverse populations would facilitate targeted interventions and policy development [34].

5 Conclusion

This study applied Latent Class Analysis (LCA) in the Thai Cohort Study (TCS) to identify four distinct patient subgroups with unique multimorbidity patterns. Apart from the “Relatively healthy” class, individuals in the other three classes (“Metabolic syndromes,” “Cardiometabolic disorders,” and “Multi-system conditions”) shared similar sociodemographic characteristics and lifestyle factors. Moreover, those with cardiometabolic disorders tended to concentrate in central Thailand. Our findings enhance understanding of non-random disease associations, informing the development of timely and effective healthcare strategies. Future research should further classify multimorbidity in diverse populations to support tailored management approaches, ultimately reducing the health burden.

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Author Contributions XF conceived and designed the study. S-AS, AS, and MK provided the database. XF analyzed and interpreted the data and drafted the manuscript. HS and MK revised the manuscript for intellectual content. XF and MK are the guarantors of the paper. All authors contributed to the article and approved the submitted version.

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Availability of Data and Materials No datasets were generated or analysed during the current study.

Declarations

Conflict of Interest The authors declare no competing interests.

Ethics Approval and Consent to Participate The studies involving humans were approved by the ethics committee of the Sukhothai Thammathirat Open University Research and Development Institute (protocol number: 0522/10). For this sub-sample analysis, we also got approval from Human Research Ethics Committee of the Australian National University (protocol number: 2004/344, 2009/570, 2021/796). The participants provided their written informed consent to participate in this study.

Consent for Publication We confirm that no other studies similar to this article are under consideration and that the content of this article has not been published previously. All authors have read and approved the final manuscript to be published.

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Supplementary Table S1. The associated factors in the Thai Cohort Study (TCS).

Domain	Variables*
Socio-demographic factors	Gender: male (reference) or female
	Age (years): ≤ 39 (reference) or 40-59 or ≥ 60
	Marital status: living with partner (including married, reference) or single
	Geographic regions: Bangkok (reference) or Central or North or Northeast or East or South
	Life course residence**: Rural-rural (lifelong ruralites, RR) (reference) or Rural-urban (urbanizers, RU) or Urban-rural (de-urbanizers, UR) or Urban-urban (urbanites, UU)
	Personal monthly income (baht)***: ≤ 7000 (reference) or 7001-10000 or 10001-20000 or ≥ 20001 (One US dollar were equivalent to around 35 Baht in 2013.)
	Monthly household income (baht)#: ≤ 7000 (reference) or 7001-10000 or 10001-20000 or ≥ 20001 (One US dollar were equivalent to around 35 Baht in 2013.)
Health behaviours/ Personal lifestyles	Educational levels: junior school (reference) or high school or diploma or university
	Deep fried food, Instant food, Soft drinks and Fast food: less than once a month (reference) or 1-3 times a month or 1-2 times a week or 3-6 times a week or and daily or more
	Dietary consumption Fruits, Vegetables and Sugar (serves/day)##: 0-4 (reference) or 5-9 or 10-14 or ≥ 15.
	Weekly exercise###: 0-7 (reference) or 8-14 or ≥ 15;
	Housework: 1-3 times a month (reference) or 1-2 times a week or 3-4 times a week or every day or more; Activity status Sleeping time (hours/day): ≤ 6 hours or 7-8 hours (reference) or ≥ 9 hours; Sedentary time (hours/day): ≤ 7 hours (reference) or 8-12 hours or ≥ 13 hours

	Smoking status: non-current smoker (reference) or current smoker;
Smoking and Drinking status	Drinking status: never (reference) or ex-drinker or occasional social or current regular.

Variables*: For each set of associations, we adjusted for other factors as confounders based on our descriptive data and observations from the rest of the literature [5, 9, 20].

Life course residence**: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) [5, 16, 19, 20].

Monthly personal income (Baht)***: The average level of personal monthly income was around 8,700 Baht in Thailand in 2013 [16, 19, 20].

Monthly household income (Baht)#: The average level of personal monthly income was around 24,800 Baht in Thailand in 2013 [16, 19, 20].

Fruits, Vegetables, Sugar (serves/day)###: The grouping of intake of fruits, vegetables and sugar would be consistent with that of previous articles [5, 16, 19, 20].

Weekly exercise####: there are three groups, namely “vigorous exercise over 20 minutes”, “moderate exercise over 20 minutes” and “walking for at least 10 minutes”. According to the International Physical Activity Questionnaire and the Australian Active Survey, this study used the adjusted exercise weights to assess weekly physical activity: “ $2 \times$ vigorous exercise + $1 \times$ moderate exercise + $1 \times$ number of walks per week”. The weekly exercise was divided into three groups: 0-7, 8-14 and ≥ 15 , which was consistent with the grouping of previous articles [5, 16, 19, 20].

Supplementary Table S2 The proportion of missingness for indicators of latent classes and variables included in the imputation model in TCS.

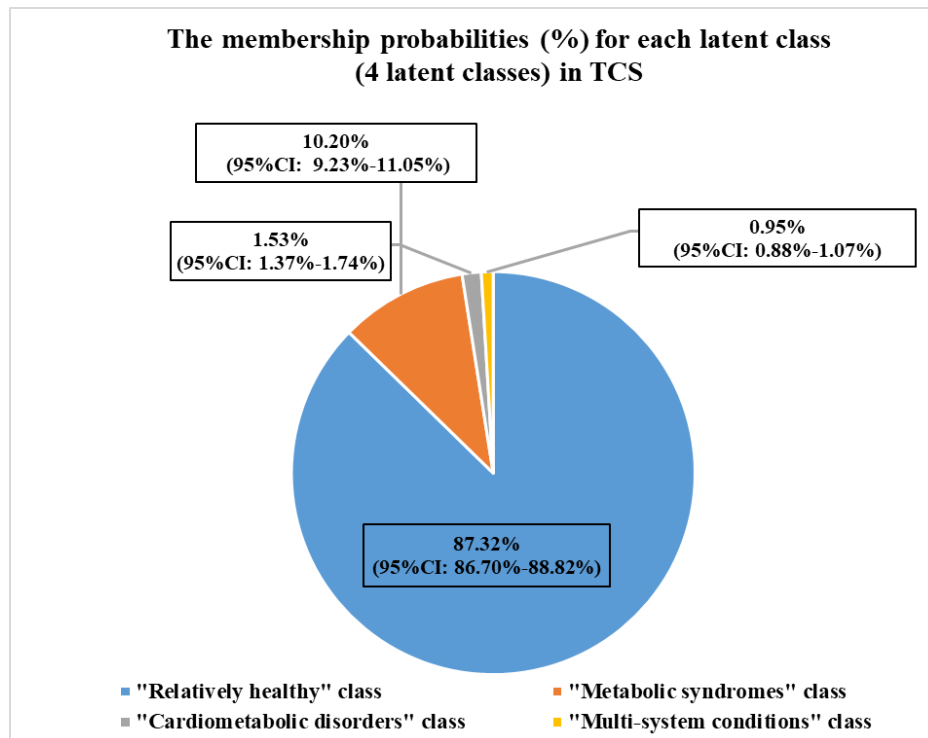
Factors	n (%) missingness
(a) Indicators of multimorbidity classes	
Obesity	320 (0.75%)
Diabetes	2584 (6.04%)
hyperlipidaemic	2035 (4.76%)
hypertension	2239 (5.23%)
Ischemic heart disease	2893 (6.76%)
Cerebrovascular disease (stroke)	2917 (6.82%)
Kidney disease	2961 (6.92%)
Cancers	0
(b) Variables used in the regression model	
Multimorbidity	0
Gender	0
Age	0
Marital status	631 (1.47%)
Geographic regions	0

Addresses (provincial level) (using in spatial analysis)	0
Life course residence	497 (1.16%)
Education level	223 (0.52%)
Monthly personal income (Baht)	464 (1.08%)
Monthly household income (Baht)	488 (1.14%)
Deep fried food	403 (0.94%)
Instant food	351 (0.82%)
Soft drink	363 (0.85%)
Fast food	386 (0.90%)
Vegetable (serves/day)	258 (0.60%)
Fruit (serves/day)	235 (0.55%)
Sugar (serves/day)	252 (0.59%)
Weekly exercise	1233 (2.88%)
Housework	469 (1.11%)
Sleeping time	337 (0.79%)
Sedentary time	570 (1.33%)
Smoking	231 (0.54%)
Drinking	341 (0.80%)

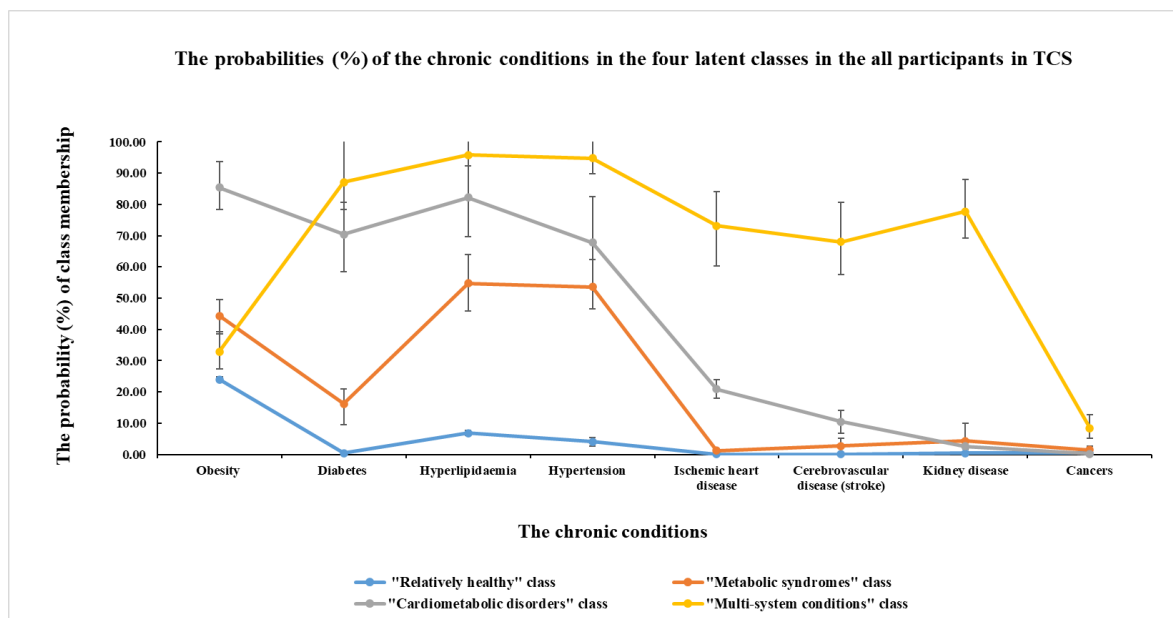
Supplementary Table S3 Comparison between models of latent class analysis in individuals in TCS.

Number of latent classes (n)	Information criteria indices			Classification quality	LMR LR	BLRT	Log likelihood	Average posterior probability
	AIC	BIC	aBIC	Entropy	(p-value)	(p-value)		
1	391456.60	391534.20	391440.54	-	-	-	-195720.28	-
2	361329.10	361494.10	361295.05	0.95	<0.0001	<0.0001	-180647.54	C1: 0.96; C2: 0.88
3	358967.30	359219.70	358942.44	0.91	<0.0001	<0.0001	-179457.66	C1: 0.68; C2: 0.92; C3: 0.86
4	358475.50	358805.60	358407.51	0.94	<0.0001	<0.0001	-179203.75	C1: 0.65; C2: 0.86; C3: 0.70; C4: 0.78;
5	358429.90	359084.40	358580.93	0.93	<0.0001	<0.0001	-179162.44	C1: 0.50; C2: 0.71; C3: 0.83; C4: 0.75; C5: 0.68
6	358417.10	359127.10	358565.09	0.89	0.08050	<0.0001	-179157.53	C1: 0.61; C2: 0.62; C3: 0.72; C4: 0.58; C5: 0.73; C6: 0.77

AIC: Akaike Information Criterion; BIC: Bayesian Information Criterion; aBIC: Adjusted Bayesian Information Criterion; LMR LR: Vuong-Lo-Mendell-Rubin likelihood ratio test; BLRT: Bootstrap-based likelihood ratio test. C1: Class 1; C2: Class 2; C3: Class 3; C4: Class 4; C5: Class 5; C6: Class 6; C7: Class 7.

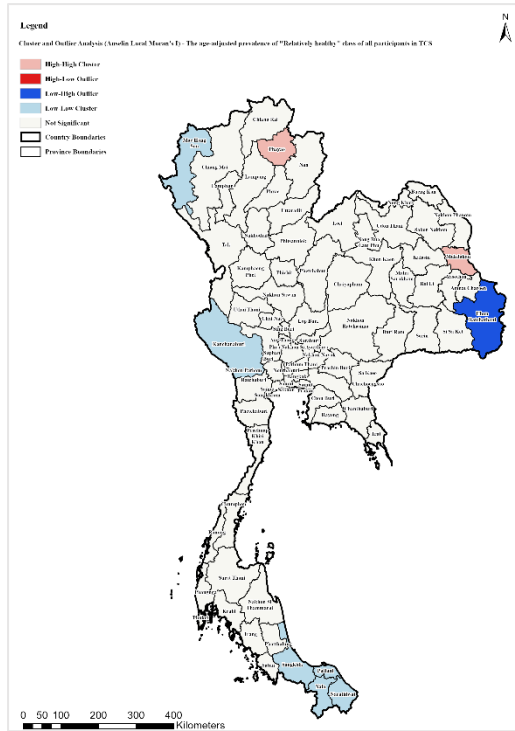


Supplementary Figure S1 The membership probabilities (%) for each latent class (4 latent classes) in TCS.

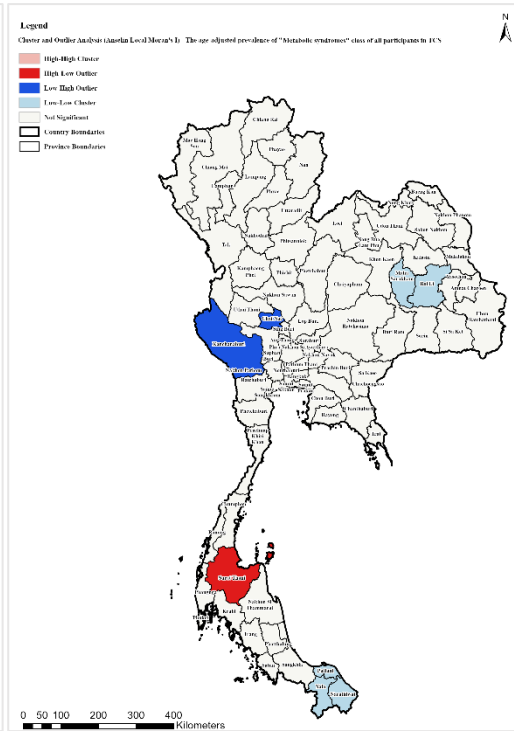


Supplementary Figure S2 The probabilities (%) of the chronic conditions in the four latent classes in all participants in TCS.

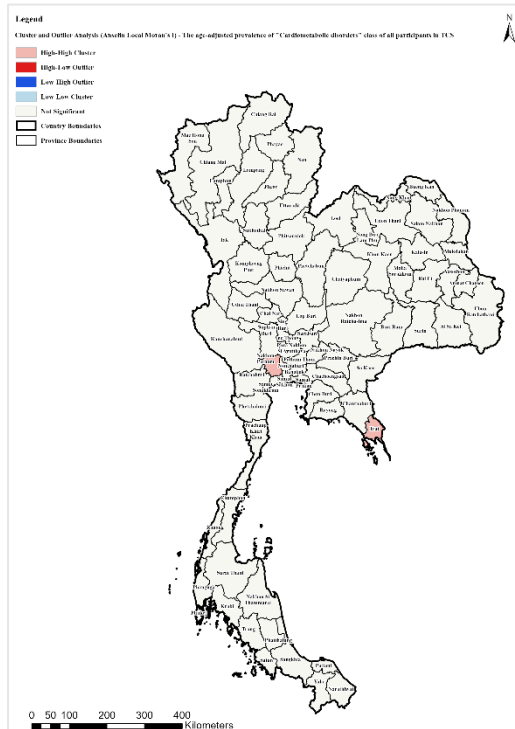
A: “Relative healthy” class



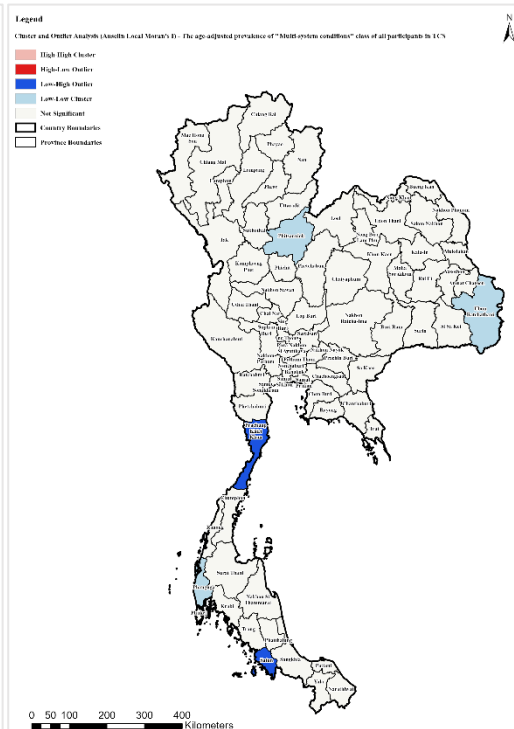
B: “Metabolic syndrome” class



C: “Cardiometabolic disorders” class



D: “Multi-system conditions” class



Models were run in 10 imputed datasets and results combined using Rubin’s rules.

Supplementary Figure S3 Cluster and Outlier Analysis (Anselin Local Moran's I) - The age-adjusted prevalence (%) of 4 latent classes in all participants in TCS.

Supplementary Table S4 The association between latent classes of multimorbidity and factors in all individuals in TCS in the completer (n=34903).

Factors	“Relatively Healthy” class (Reference class)	“Metabolic syndromes” class		“Cardiometabolic disorders” class		“Multi-system conditions” class	
		ARRR*	(95 % CI)	ARRR*	(95 % CI)	ARRR*	(95 % CI)
Socio-Demographics							
Gender (reference: male)							
Female	1.00	0.84	(0.76, 0.93)	0.63	(0.56, 0.72)	0.94	(0.85, 0.99)
Age (years) (reference: ≤ 39 years)							
40-59 years	1.00	3.50	(1.87, 5.43)	5.33	(3.06, 7.55)	2.34	(2.13, 3.91)
≥ 60 years	1.00	14.01	(9.65, 17.81)	17.87	(9.79, 35.62)	7.27	(6.70, 18.53)
p-trend		0.0097		0.0449		0.0306	
Marital status (reference: living with others)							
Single	1.00	0.94	(0.72, 1.32)	1.19	(0.95, 1.26)	1.03	(0.92, 1.30)
Geographic regions (reference: Bangkok)							
Central	1.00	0.94	(0.82, 1.08)	0.89	(0.76, 1.04)	0.82	(0.62, 1.09)
North	1.00	1.53	(1.33, 1.76)	1.07	(0.90, 1.27)	0.98	(0.76, 1.25)
Northeast	1.00	0.81	(0.69, 0.95)	0.83	(0.71, 0.98)	0.72	(0.55, 1.50)
East	1.00	0.87	(0.72, 1.06)	0.81	(0.65, 0.93)	0.65	(0.46, 1.49)
South	1.00	0.76	(0.64, 0.90)	0.56	(0.46, 0.68)	0.77	(0.31, 1.06)
Life course residence** (reference: Rural-rural (RR))							
Rural-urban (RU)	1.00	0.90	(0.81, 1.03)	0.91	(0.81, 1.02)	0.75	(0.60, 1.12)
Urban-rural (UR)	1.00	0.96	(0.80, 1.16)	1.20	(0.95, 1.51)	0.63	(0.05, 1.36)
Urban-urban (UU)	1.00	0.86	(0.76, 1.17)	0.92	(0.80, 1.05)	0.96	(0.75, 1.23)
Monthly personal income (baht) (reference: ≤ 7000 baht)							
7001-10000 Baht	1.00	1.08	(0.91, 1.29)	0.96	(0.76, 1.21)	1.15	(0.74, 1.79)
10001-20000 Baht	1.00	0.83	(0.70, 1.10)	0.77	(0.45, 1.41)	0.67	(0.45, 1.23)
≥ 20001 Baht	1.00	0.86	(0.73, 1.02)	1.12	(0.90, 1.38)	0.75	(0.58, 1.34)
p-trend		0.3082		0.6741		0.3336	
Monthly home income (baht) (reference: ≤ 7000 baht)							

7001-10000 Baht	1.00	0.76	(0.61, 1.04)	1.14	(0.40, 1.73)	0.56	(0.17, 1.13)
10001-20000 Baht	1.00	0.87	(0.56, 1.22)	1.23	(0.75, 1.41)	0.88	(0.18, 1.42)
≥ 20001 Baht	1.00	0.89	(0.50, 1.71)	1.02	(0.53, 1.63)	1.06	(0.31, 1.78)
p-trend		0.8015		0.8955		0.6192	
Educational level (reference: Junior school)							
High school	1.00	0.54	(0.40, 1.23)	0.26	(0.13, 0.73)	0.83	(0.43, 1.62)
Diploma	1.00	0.50	(0.36, 1.39)	0.65	(0.35, 0.89)	0.73	(0.36, 1.46)
University	1.00	0.70	(0.47, 0.93)	0.42	(0.16, 0.77)	0.68	(0.44, 0.90)
p-trend		0.4656		0.4572		0.0457	
Health behaviours/Personal lifestyles							
Diet consumptions							
Deep fried food (reference: Never)							
1-3 times/month	1.00	1.08	(0.89, 1.32)	0.94	(0.63, 1.40)	1.54	(1.02, 2.32)
1-2 times/week	1.00	1.14	(0.77, 1.54)	1.06	(0.72, 1.56)	1.80	(1.20, 2.69)
3-6 times/week	1.00	0.86	(0.70, 1.05)	1.10	(0.68, 1.48)	1.13	(0.75, 1.71)
Daily or more	1.00	1.46	(0.80, 1.95)	0.71	(0.33, 1.29)	0.74	(0.45, 1.38)
p-trend		0.3950		0.4664		0.7338	
Instant food (reference: Never)							
1-3 times/month	1.00	1.26	(0.95, 1.51)	0.99	(0.86, 1.14)	0.96	(0.75, 1.23)
1-2 times/week	1.00	1.03	(0.91, 1.48)	1.08	(0.90, 1.30)	1.23	(0.89, 1.69)
3-6 times/week	1.00	1.12	(0.78, 1.61)	1.70	(0.51, 2.22)	1.94	(0.25, 3.00)
Daily or more	1.00	1.64	(0.82, 3.29)	1.76	(1.04, 1.93)	1.17	(0.52, 1.42)
p-trend		0.1961		0.0641		0.3622	
Soft drink (reference: Never)							
1-3 times/month	1.00	0.81	(0.66, 1.38)	1.04	(0.89, 1.20)	0.97	(0.74, 1.26)
1-2 times/week	1.00	1.03	(0.80, 1.31)	0.92	(0.68, 1.29)	1.10	(0.79, 1.53)
3-6 times/week	1.00	0.95	(0.72, 1.24)	0.83	(0.65, 1.69)	1.12	(0.78, 1.60)
Daily or more	1.00	0.85	(0.87, 1.26)	1.31	(0.71, 1.92)	1.07	(0.28, 1.93)
p-trend		0.6649		0.5539		0.1790	
Fast food (reference: Never)							
1-3 times/month	1.00	1.17	(0.96, 1.41)	1.06	(0.91, 1.23)	0.71	(0.54, 1.54)
1-2 times/week	1.00	0.42	(0.28, 1.64)	0.83	(0.63, 1.10)	0.94	(0.59, 1.51)

3-6 times/week	1.00	1.31	(0.86, 1.98)	1.21	(0.93, 1.87)	0.02	(0.00, 4.07)
Daily or more	1.00	1.96	(0.84, 3.47)	1.88	(0.42, 2.39)	4.03	(0.65, 6.57)
p-trend		0.2989		0.1493		0.3404	
Vegetable (serves/day) (reference: 0-4)							
5-9	1.00	1.01	(0.68, 1.47)	1.16	(0.86, 1.56)	0.84	(0.01, 1.32)
10-14	1.00	0.78	(0.51, 1.32)	0.31	(0.19, 1.47)	7.63	(0.23, 8.55)
≥ 15	1.00	0	-	0	-	0	-
p-trend		0.0645		0.0763		0.8951	
Fruit (serves/day) (reference: 0-4)							
5-9	1.00	1.59	(0.85, 1.99)	1.05	(0.87, 1.27)	0.60	(0.41, 1.86)
10-14	1.00	1.14	(0.15, 1.95)	3.13	(0.04, 4.42)	1.97	(0.22, 4.36)
≥ 15	1.00	0	-	0	-	0	-
p-trend		0.1715		0.6992		0.5751	
Sugar (serves/day) (reference: 0-4)							
5-9	1.00	0.72	(0.57, 1.32)	0.98	(0.76, 1.27)	1.54	(0.97, 2.44)
10-14	1.00	0.17	(0.02, 1.28)	1.37	(0.58, 9.76)	1.83	(0.76, 4.90)
≥ 15	1.00	0	-	1.20	(0.02, 2.35)	0	-
p-trend		0.0778		0.4234		0.3484	
Physical activities							
Weekly exercise# (reference: 0-4)							
8-14	1.00	0.96	(0.86, 1.32)	1.09	(0.78, 1.92)	1.28	(0.65, 1.57)
≥ 15	1.00	0.89	(0.75, 0.97)	0.83	(0.64, 1.88)	0.76	(0.52, 2.33)
p-trend		0.0582		0.1798		0.8640	
Housework (reference: Never)							
1-3 times/month	1.00	1.40	(0.77, 1.74)	1.03	(0.98, 1.53)	0.49	(0.31, 0.62)
Once or twice/week	1.00	1.31	(0.49, 1.61)	0.98	(0.89, 1.11)	0.37	(0.27, 0.51)
3-4 times/week	1.00	0.89	(0.71, 1.11)	0.87	(0.77, 0.98)	0.39	(0.27, 0.56)
Every day or more	1.00	1.29	(0.81, 1.59)	0.83	(0.67, 0.04)	0.31	(0.23, 0.43)
p-trend		0.8360		0.0327		0.0787	
Sleeping time (reference: 7-8 hours)							
≤ 6 hours	1.00	0.98	(0.86, 1.03)	0.97	(0.87, 1.07)	0.93	(0.45, 1.32)
≥ 9 hours	1.00	0.91	(0.81, 1.18)	1.54	(0.60, 2.01)	1.08	(0.89, 1.69)

p-trend		0.5423		0.3767		0.0977	
Sedentary time (reference: ≤ 7 hours)							
8-12 hours	1.00	1.02	(0.91, 1.09)	0.97	(0.88, 1.08)	0.96	(0.72, 1.78)
≥ 13 hours	1.00	0.81	(0.70, 1.13)	1.19	(0.79, 1.39)	0.64	(0.53, 1.28)
p-trend		0.3475		0.3728		0.2279	
Smoking and drinking status							
Smoking (reference: Non-current smoker)							
Current smoker	1.00	1.15	(1.02, 1.46)	1.17	(0.82, 1.21)	1.94	(0.56, 2.31)
Drinking (reference: Never)							
Ex-drinker	1.00	1.30	(1.08, 1.73)	1.15	(1.04, 1.48)	1.11	(0.60, 1.99)
Occasional or social	1.00	0.96	(0.70, 1.12)	0.67	(0.61, 1.72)	0.58	(0.13, 2.04)
Current regular	1.00	1.09	(0.43, 2.17)	1.01	(0.81, 1.26)	0.70	(0.22, 2.31)
p-trend		0.3157		0.7146		0.7044	

ARRR*: Adjusted Relative risk ratios from multinomial logistic regression models of latent class controlling for socio-demographic factors, and health behaviours.

95% CI: 95% confidential intervals.

ARRR **bolding**: The results of ARRR were statistical significance ($p < 0.05$).

p-trend **bolding**: The results of p-trend were statistical significance (p for trend < 0.05).

Life course residence**: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10-12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites [12, 16, 19, 20].

Weekly exercise#: there are three groups, namely “vigorous exercise over 20 minutes”, “moderate exercise over 20 minutes” and “walking for at least 10 minutes”. According to the International Physical Activity

Questionnaire and the Australian Active Survey, this study used the adjusted exercise weights to assess weekly physical activity: “ $2 \times$ vigorous exercise + $1 \times$ moderate exercise + $1 \times$ number of walks per week”. The weekly exercise was divided into three groups: 0-7, 8-14 and ≥ 15 , which was consistent with the grouping of previous articles [12, 16, 19, 20].

Chapter 9 Multimorbidity and all-cause mortality in Thailand

Building on the analyses presented in previous chapters, which examined the prevalence and patterns of multimorbidity by age and sex, identified the risk factors, explored geographic disparities, and characterized latent classes of co-occurring chronic conditions, this chapter investigates the impact of multimorbidity and associated risk factors on adult survival in Thailand. Using mortality data from the Thai Cohort Study (TCS), we assess how multimorbidity, along with sociodemographic characteristics and health-related behaviours, influences mortality risk. Both independent and combined effects of these factors are considered, allowing a comprehensive understanding of their contributions to survival outcomes.

By integrating the insights from previous chapters, this analysis aims to inform healthcare policy and resource allocation in the context of Thailand's demographic transition. Furthermore, the findings provide evidence to support the design of targeted interventions that may prevent or mitigate multimorbidity, ultimately contributing to reductions in mortality within affected populations.

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

Title: The impact of multimorbidity on all-cause mortality: A longitudinal study of 87,151 Thai adults

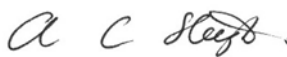
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Contribution to paper: XF conceived the study, analysed and interpreted the data and drafted the manuscript. XF, HS and MK designed the study. SS, AS and MK provided the dataset. XF, HS and MK contributed to subsequent drafts and final editing.

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The Impact of Multimorbidity on All-Cause Mortality: A Longitudinal Study of 87,151 Thai Adults

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Objectives: To investigate associations between multimorbidity, socio-demographic and health behaviour factors, and their interactions (multimorbidity and these factors) with all-cause mortality among Thai adults.

Methods: Associations between multimorbidity (coexistence of two + chronic diseases) and mortality between 2005 and 2019 were investigated among Thai Cohort Study (TCS) participants ($n = 87,151$). Kaplan-Meier survival curves estimated and compared survival times. Multivariate Cox proportional hazards models examined associations between risk factors, and interactions between multimorbidity, these factors, and survival.

Results: 1,958 cohort members died between 2005 and 2019. The risk of death was 43% higher for multimorbid people. In multivariate Cox proportional hazard models, multimorbidity/number of chronic conditions, age, long sleep duration, smoking and drinking were all independent factors that increased mortality risk. Women, urbanizers, university education, over 20,000-baht personal monthly income and soybean products consumption lowered risk. The interactions between multimorbidity and these variables (except for female, urbanizers and soybeans intake) also had significant ($p < 0.05$) impact on all-cause mortality.

Conclusion: The results emphasise the importance of healthy lifestyle and reduced intake of alcohol and tobacco, in reducing premature mortality, especially when suffering from multimorbidity.

Keywords: all-cause mortality, lifestyle behaviour, multimorbidity, socio-demographics status, Thai Cohort Study

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INTRODUCTION

Multimorbidity refers to the co-existence of two or more chronic health conditions in a person [1, 2]. Moreover, the incidence of multimorbidity is positively correlated with increasing age [3]. While the proportion of the global population aged 60 or over was 9.8% in 2017, this proportion is projected to increase to 13.7% and 20.3% by 2030 and 2050 respectively. Older people face a variety of health problems, with multimorbidity being one of the most pressing [1, 2]. However, in recent years, a growing number of studies has found that multimorbidity has gradually ceased to be exclusive disease of the elderly and are becoming more prevalent among younger people [4, 5].

To date, approximately one-third of the global population worldwide suffers from multimorbidity, and this proportion is projected to rise by 2035 [2], which will pose a number

of challenges to the health of the global population worldwide [1, 2]. The negative impacts of multimorbidity include an increased likelihood of disability, reduced quality of life and increased risk of death [3]. Evidence suggests that patients with multimorbidity are approximately 1.5 times more likely to die compared to those without multimorbidity [3]. In addition, studies in the UK [6] and China [7] have shown that all-cause mortality is higher in people with multimorbidity than in people without multimorbidity, and that the relative impact of an increased number of long-term chronic conditions on the increased risk of death is greater in younger and middle-age (around 35–50 years old) people [6]. Therefore, the management of multimorbidity has become a public health imperative.

Many factors which associate with multimorbidity such as age, gender, socioeconomic status (SES) and health behaviour have not been adequately studied in terms of their impact on the relationship between multimorbidity and mortality [8, 9]. For example, people with low SES [10] and those with risky individual health behaviours [11] may be more susceptible to multimorbidity. However, the impact of these factors on mortality, particularly for people with multimorbidity, has not been adequately studied. In particular, in low- and middle-income countries (LMICs) where multimorbidity is relatively under-researched, compared to high-income countries (HICs) [12].

Multimorbidity is a common condition in Southeast Asia, with a prevalence of about 16%. [13, 14], but there is relatively little research about this health burden in Southeast Asia [13, 14]. Thailand, a Southeast Asian country, is facing a health transition in disease patterns and causes of death. Non-communicable diseases (NCDs) such as diabetes and hypertension, are now the leading causes of death in Thailand [15]. However, little information is available on the interactions between the multimorbidity posed by these chronic conditions and the risk factors contributing to all-cause mortality. To better examine the relationship between multimorbidity and all-cause mortality in the Thai population, data from a long-term community-based cohort study in Thailand, the Thai Cohort Study (TCS), were used here. The TCS has studied more than 85,000 Thais living across the country since 2005, with a similar demographic profile of participants to the national population [15].

The aim of this study was to investigate whether multimorbidity and risk factors (socio-demographic and health behaviour factors) have a significant impact on survival in adults by independently analysing multimorbidity and risk factors, their interactions, and associations with mortality risk. It may be useful in order to inform health policy and health resource allocation in such a transitional context, and to design appropriate interventions to prevent or reduce the occurrence of multimorbidity and thereby reduce mortality.

METHODS

The Study Population

The data used were from the longitudinal study of health transitions in Thailand, known as the Thai Cohort Study

(TCS). Participants in the study were adults living throughout Thailand and attending Sukhothai Thammathirat Open University (STOU) [15, 16]. A comprehensive health questionnaire was mailed to all students in 2005 and over 80,000 people (age range: 15–87 years) responded. The questionnaire covered a wide range of topics, including socio-demographic data, indicators of health status, health behaviours and history of physician-diagnosed disorders [17].

Mortality Data

TCS participants represented the median age of STOU's student population and the total Thai population. They also represent the Thai population in terms of gender balance, ethnicity, religion, modest income, and geographical distribution. They are however on average more highly educated than Thais in general. Upon enrolment in the TCS, all participants were asked to provide a Citizenship Identification Number (CID), a unique 13-digit identification used for all government interactions [14]. The CID list of all TCS members was regularly checked against government death records maintained by the Thai Ministry of Interior [18]. For our study, we considered deaths among TCS members reported by the Ministry of Interior occurring between March 2005 and December 2019, for a total of 1,958 deaths. It was observed that the estimates of vital statistics kept in Thailand during our study period of high quality and completeness and were found to record 95% or more of the deaths [15, 18].

The Definition of Multimorbidity

In our study, multimorbidity was defined as a person with two or more chronic conditions at the same time [1–3]. In the 2005 TCS baseline questionnaire, one of the questions was whether the respondent had been diagnosed by a doctor with any of the 18 diseases listed, with those with these illnesses reporting “yes” and those without them reporting “no” [15, 16]. Participants also recorded their weight and height, and BMI was calculated from these variables. Obesity was then defined as having a body mass index (BMI) greater than 25, with BMI greater than 25 classified as “yes” and BMI less than 25 classified as “no” [18]. Based on the specific cut-off for Asian populations, a BMI above 25 kg/m² is defined as obese, rather than the WHO definition of over 30 kg/m² as obese [19, 20]. Therefore, there were 18 disorders in our study. These chronic conditions were metabolic disorders: cardiometabolic conditions (diabetes, high cholesterol/high blood lipids, high blood pressure, ischemic (coronary) heart disease, cerebrovascular disease (stroke)), obesity, liver disease and kidney disease; endocrine disorders; goiter/thyroid abnormality; musculoskeletal disorders: arthritis; brain and emotional disorders: depression/anxiety and epilepsy; respiratory disorders: chronic bronchitis/lung disease and asthma; cancers: liver cancer, lung cancer, breast cancer and cancer of the digestive system. Multimorbidity was defined as the same individual having two or more of these 18 diseases being reported as “yes”. There was also created the other variable with more precise information on the number of

chronic diseases named as the number of chronic conditions (0, 1, 2, 3, 4 or more chronic conditions, CC) [1].

Independent Variables

The other factors were divided into two groups. The first group was socio-demographic factors, which included gender (male (reference) or female), age (years, ≤ 39 (reference) or 40–59 or ≥ 60), marital status (single (reference) or living with partner or married), geographic regions (Bangkok (reference) or Central or North or Northeast or East or South), life course residence (Rural-rural (lifelong ruralites, RR) (reference) or Rural-urban (urbanizers, RU) or Urban-rural (de-urbanizers, UR) or Urban-urban (urbanites, UU)), personal monthly income (baht, ≤ 7000 (reference) or 7,001–10,000 or 10,001–20,000 or $\geq 20,001$) and educational level (junior school (reference) or high school or diploma or university).

Among them, life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) [16, 19, 21, 22]. As for personal monthly income, One US dollar were equivalent to around 25 Baht in 2005 [13].

The second group was health behaviours or personal lifestyles, which included dietary consumptions (deep fried food, instant food, soft drinks, soybean products: less than once a month (reference) or 1–3 times a month or 1–2 times a week or 3–6 times a week or daily or more; fruits and vegetables: 0–4 (reference) or 5–9 or 10–14 or ≥ 15). The grouping of intake of fruits and vegetables would be consistent with that of previous articles [16, 19, 21, 22].

As for the active status, there were four groups and the first one is weekly exercise. Information on weekly exercise was obtained by asking: “during a typical week (7-day period) how many times on average do you do each of these physical activities”: “vigorous exercise over 20 min,” “moderate exercise over 20 min” and “walking for at least 10 min.” In this study, however, we used these three indicators to calculate the adjusted exercise measure (number of sessions): “2 $\times$ vigorous exercise +1 $\times$ moderate exercise +1 $\times$ number of walks per week” to weight weekly activity intensity. This adjusted exercise measure was based on the International Physical Activity Questionnaire and the Australian Active Survey (IPAQ and AAS) [21, 22], since the question of weekly exercise is a sessions-based measure of physical activity, similar to the sessions component of the is similar to IPAQ and AAS, and many studies in TCS used this measure to weight weekly exercise [19, 21, 22]. Finally, weekly exercise was recoded as “0–7 sessions” (reference) or “8–14 sessions” or “more than 15 sessions,” which was consistent with the grouping of previous articles [21, 22]. The other three groups were the frequency of housework (1–3 times a month (reference) or 1–2 times a week or 3–4 times a week or every day or more), sleeping time (hours/day: ≤ 6 h or 7–8 h (reference) or ≥ 9 h) and sedentary time (hours/day: ≤ 7 h (reference) or 8–12 h or ≥ 13 h).

In terms of smoking, there were two measures on the questionnaire, the first being never smoking (reference) and the second being smoking, including former smokers who

have now quit and those who have always smoked. As for drinking status, information was obtained by asking participants and through their self-report: “Have you ever drunk alcohol”: “Occasional social drinker,” “No, never” (reference), “Current regular drinker” or “Used to drink before, now stopped” (ex-drinker).

Statistical Analysis

The main variable of interest was whether the cohort member died between March 2005 and December 2019. A stratified analysis has been performed for gender and age (Table 3). We described the distribution of deaths by individual characteristics of cohort members: participants, multimorbidity, number of chronic conditions (5 categories), age groups (3 categories), marital status (3 categories), regions area of residence (geographic regions, 6 categories), life course residence (urban or rural resident at age 10 to 12 and in 2005), education level (4 categories) and monthly income (4 categories, baht, US\$1 was equal to 25 baht in 2005). We used Stata 16.0 to tackle the analysis.

Kaplan Meier survival curves display explain multimorbidity or not/different number of chronic conditions by baseline in 2005. End-point events were all-cause deaths until 2019. We used the log-rank test to test the statistical probability of observed difference in survival patterns according to having multimorbidity or not/different number of chronic conditions. Univariate and multivariate Cox proportional hazards models were used to examine the association between risk factors (including multimorbidity and the number of chronic conditions) and survival [23]. Multivariate Cox proportional hazards models were also used to evaluate the association between the interaction between multimorbidity and these independent variables, and survival. Hazard ratios (HR) and 95% confidence intervals (95% CI) were generated as the results [23]. For each set of associations, we adjusted other factors in Table 2 for confounders. For any missing data, our study assumed that they were missing at random. For all analyses, p for trend (p -trend) were used to test the linear trend and p values < 0.05 were considered statistically significant. All statistical analyses were performed using Stata 16.0.

Ethical Approval

All participants obtained informed written consent and were informed that they could withdraw or not participate in the study without affecting their academic progress.

The Thai Cohort Study (TCS) has been approved by the ethic committee of the Sukhothai Thammathirat Open University Research and Development Institute (protocol number: 0522/10). For this sub-sample analysis, we also got approval from Human Research Ethics Committee of the Australian National University (protocol number: 2004/344, 2009/570, 2021/796).

RESULTS

Cohort Characteristics by Survival Status at the Baseline

A total of 1,958 members of the Thai Cohort Study died between 2005 and 2019. The distribution of these deaths across

socioeconomic and demographic groups is reported in **Supplementary Table S1** in **Supplementary File S1**. Among deceased cohort members, males accounted for approximately 70% of the total deaths. The cumulative mortality in the groups of having multimorbidity and/or more than 4 chronic conditions (CC) were higher than other groups. Rural groups accounted for a higher proportion of deaths, particularly those who had lived in rural areas since childhood. In addition, groups under 39 years of age, high school graduates and those earning less than 7,000 baht per month were more likely to be in the death group.

Survival Analysis

As for the Kaplan-Meier analysis (see **Figure 1A**), the 15 years cumulative survival probabilities in male participants were 96.55% (95% CI: 96.37%–96.73%) and for female members were 98.75% (95% CI: 98.65%–98.85%) ($p < 0.0001$). Moreover, the cumulative survival probabilities of all members at 15 years were 97.75% (95% CI: 97.65%–97.85%) (see **Figure 1B**). Significant differences (all p -value < 0.0001) in cumulative survival time were shown among multimorbid patients and others (see **Figures 2A–C**). The 15 years cumulative survival probabilities in males with multimorbidity were 94.48% (95% CI: 93.89%–95.02%), female with multimorbidity were 97.35% (95% CI: 96.80%–97.81%) and all people with multimorbidity were 95.58% (95% CI: 95.16%–95.96%).

In the analysis of multimorbidity and other risk factors of mortality (see **Table 1** and **Supplementary Table S2** in **Supplementary File S1**), people with multimorbidity (compared to others without multimorbidity; hazard ratio (HR): 2.29, 95% CI: 2.06–2.54, adjusted hazard ratio (AHR): 1.43, 95% CI: 1.26–1.62), older age (compared to less than 39 years old people; 40–59 years old: HR: 2.84, 95% CI: 2.58–3.13, AHR: 2.33, 95% CI: 2.03–2.67; over 60 years old: HR: 18.47, 95% CI: 14.88–22.93, AHR: 11.46, 95% CI: 8.58–15.30), sleeping over 9 h (compared to sleeping time between 7–8 h; HR: 1.19, 95% CI: 1.04–1.36, AHR: 1.25, 95% CI: 1.08–1.44), smoking (compared to non-smokers; smoking: HR: 2.58, 95% CI: 2.36–2.82, AHR: 1.41, 95% CI: 1.24–1.60), drinking (compared to non-drinkers; ex-drinker: HR: 0.81, 95% CI: 0.72–0.91, AHR: 1.17, 95% CI: 1.01–1.35; social drinker: HR: 2.22, 95% CI: 1.90–2.59, AHR: 1.37, 95% CI: 1.15–1.63; regular drinker: HR: 2.02, 95% CI: 1.78–2.29, AHR: 1.44, 95% CI: 1.25–1.67) independently predicted much poorer cumulative survival. Moreover, the more frequently alcohol was consumed, the worse the cumulative survival probability (p -trend = 0.0160).

On the other hand (see **Table 1** and **Supplementary Table S2** in **Supplementary File S1**), female participants (compared to men; HR: 0.36, 95% CI: 0.33–0.40, AHR: 0.53, 95% CI: 0.46–0.61), people who were urbanised (Rural-urban (RU), HR: 0.91, 95% CI: 0.81–1.01, AHR: 0.84, 95% CI: 0.74–0.95), compared to participants who were lifelong ruralites (Rural-rural, RR), completion of university degree (compared to members with primary school; HR: 0.39, 95% CI: 0.32–0.47, AHR: 0.68, 95% CI: 0.55–0.86), monthly personal income over 20,000 baht (compared to members with less 7,000 baht per month; HR:

1.64, 95% CI: 1.42–1.88, AHR: 0.80, 95% CI: 0.66–0.97) and consuming soybean products 1–3 times per month (compared to people who never eating soybean products; HR: 0.80, 95% CI: 0.69–0.92, AHR: 0.85, 95% CI: 0.72–0.99) showed better cumulative survival. As for activity status, the risk of death declined more for women who did housework more frequently, with a linear trend (p -trend = 0.0450).

Furthermore, with regard to the number of chronic conditions (CC), in the comparison with people without chronic conditions, the higher the number of conditions, the higher the risk of death among these participants (one CC: HR: 1.64, 95% CI: 1.48–1.82; two CC: HR: 2.41, 95% CI: 2.11–2.76; three CC: HR: 3.29, 95% CI: 2.70–4.02; over four CC: HR: 4.15, 95% CI: 3.19–5.40) in crude analysis, with a linear trend (p -trend = 0.0001) (**Supplementary Table S2** in **Supplementary File S1**). Such a trend would be also unchanged after controlling for socio-demographic and behavioural factors (see **Table 1**), compared to individuals with no chronic conditions, having one chronic disease may increase the risk of death by 34%, while having two diseases may increase the risk by 52%, having three diseases would near double the risk, and four and more diseases would be an 87% risk, which would be close to a linear increase (p -trend = 0.0098).

The more the number of chronic diseases people suffered from, the lower the probability of survival they were ($p < 0.0001$) (see **Figures 2D–F**). The 15 years cumulative survival probability was 1.03% lower for all people with one disease than for people without chronic diseases, 2.25% lower for two diseases, 4.29% lower for three diseases, and 5.00% lower for four or more diseases, which was a significant linear relationship (p -trend = 0.0011).

For all people (see **Figures 3A–C**), the 15 years survival probability of multimorbidity decreased when the age increased (less than 39 years old: 97.15% (95% CI: 96.72%–97.53%) vs. 40–59 years old: 93.92% (95% CI: 93.11%–94.64%) vs. over 60 years old: 69.18% (95% CI: 61.00%–75.98%). The risk of death for multimorbidity was significantly increased when people got older but there was no linear relationship between them (see **Table 2**). In terms of the number of chronic conditions (see **Figures 3D–F**; **Table 2**), a statistically significant difference was found between number of chronic conditions and overall survival time in different age groups ($p < 0.0001$, except over 60 years old group ($p = 0.5524$)). The risk of death increased with age for the same number of diseases, but there was no significant linear relationship. In the group of 40–59 years old, the risk of death increased with increased number of chronic conditions, with the significant linear relationship (p -trend = 0.0070).

As for the impact of interactions between multimorbidity and risk factors on all-cause mortality (see **Table 3**), in the adjusted model (controlling socio-demographic and behavioural factors), females with multimorbidity had 6% lower risk of death than males without multimorbidity, but this result was not statistically significant. There is a linear increase (p -trend = 0.0413) in the risk of death with age for people with multimorbidity in comparison to people younger

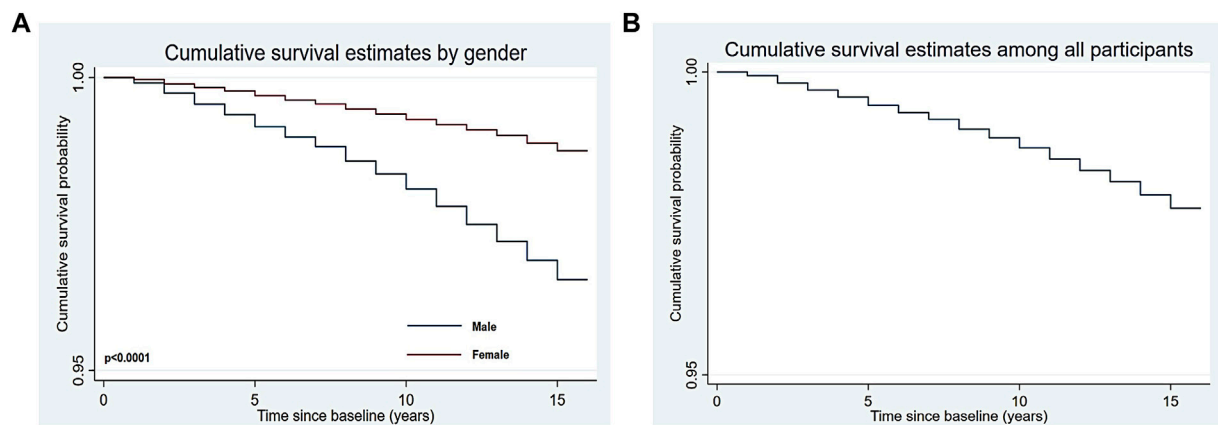


FIGURE 1 | Kaplan-Meier estimated curves for cumulative survival **(A)** for male and female; **(B)** for all participants (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

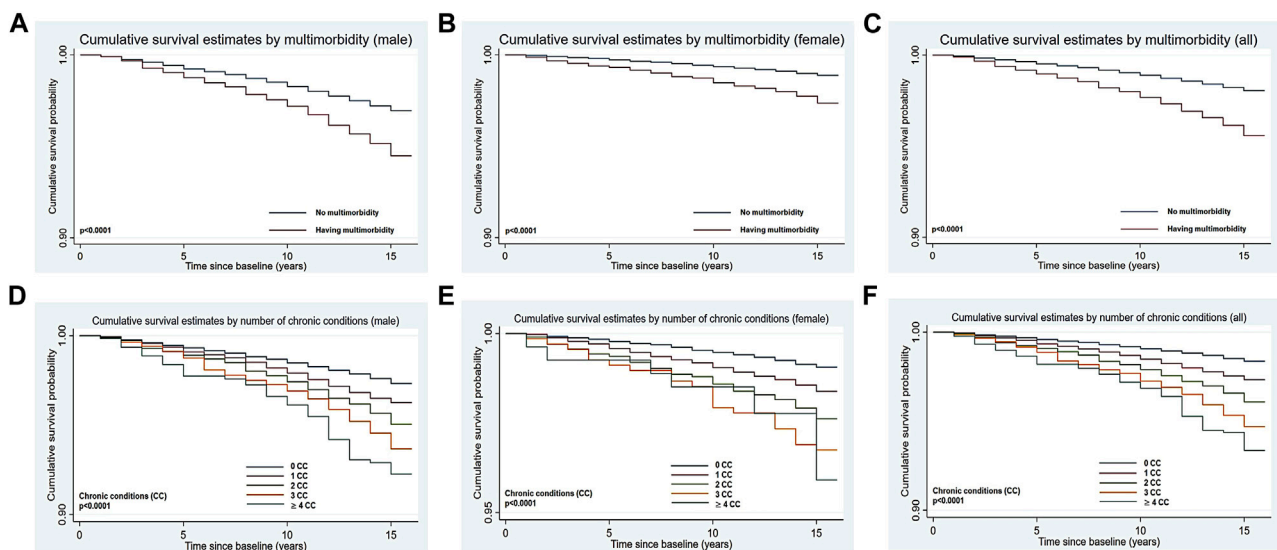


FIGURE 2 | Kaplan-Meier estimated curves for cumulative survival by multimorbidity **(A)** for male; **(B)** for female; **(C)** for all) or number of chronic conditions **(D)** for male; **(E)** for female; **(F)** for all, and gender (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

than 39 years who do not have multimorbidity. In the terms of socio-economic status (SES), higher-income and better-educated (high SES) multimorbid people have a lower risk of death (AHR: 0.49, 95% CI: 0.32–0.75) than healthy people with low SES. Members with multimorbidity have a significantly (all $p < 0.05$) increased risk of death, regardless of the amount of sleep they get, compared to normal participants (without multimorbidity) who get a normal amount of sleep (7–8 h).

However, it is worth noting that multimorbid patients with 7–8 h (AHR: 1.31, 95% CI: 1.10–1.51) of sleep had a slightly lower risk of death than those with abnormal sleep schedules

(less than 6 h: AHR: 1.51, 95% CI: 1.25–1.83; more than 9 h: AHR: 2.01, 95% CI: 1.52–2.66). Individuals who smoked and had multimorbidity were 1.05 times more likely to be at risk of death than those who did not smoke and did not have multimorbidity. Participants with multimorbidity have an increased risk of death whether they drink alcohol or not, compared to healthy people who never drink alcohol. While alcohol consumption increased the risk of death even more. The risk of death increases 43% for the multimorbid individuals that never drinks alcohol and 102% for the multimorbid members that drinks alcohol regularly (see **Table 3**).

TABLE 1 | Multivariate adjusted hazard ratios according to multimorbidity, the number of chronic conditions (CC) and risk factors (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

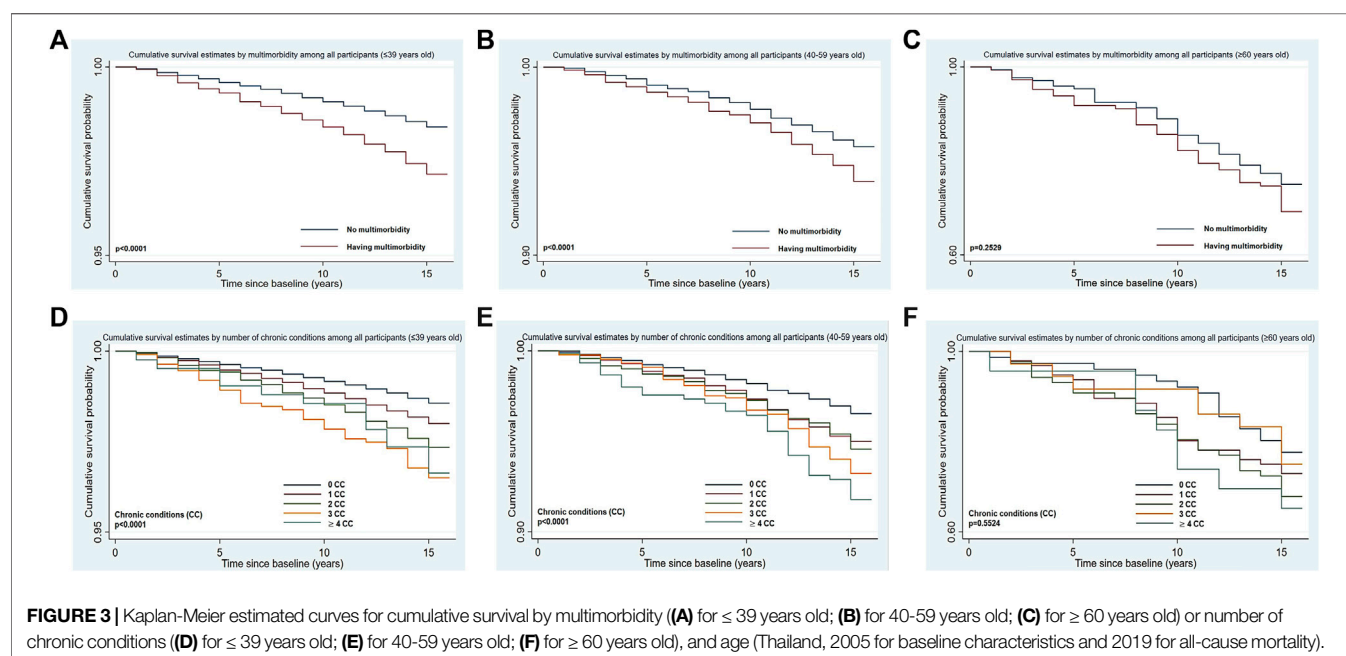
Participants						
	Male		Female		Total	
	AHR*	(95% CI)	AHR*	(95% CI)	AHR*	(95% CI)
Two or more chronic conditions						
Multimorbidity						
No	1.00		1.00		1.00	
Yes	1.36	(1.18, 1.57)	1.76	(1.38, 2.25)	1.43	(1.26, 1.62)
Number of chronic conditions (CC)						
0 CC	1.00		1.00		1.00	
1 CC	1.23	(1.07, 1.42)	1.57	(1.29, 1.92)	1.34	(1.20, 1.51)
2 CC	1.40	(1.16, 1.68)	1.87	(1.38, 2.53)	1.52	(1.30, 1.78)
3 CC	1.74	(1.35, 2.25)	2.77	(1.74, 4.42)	1.92	(1.54, 2.41)
≥4 CC	1.69	(1.19, 2.41)	3.00	(1.52, 5.90)	1.87	(1.37, 2.55)
p-trend	0.0097		0.0022		0.0098	
Socio-demographic factors						
Gender	1.00		0.53	(0.46, 0.61)		
Age (years)						
≤39 years	1.00		1.00		1.00	
40–59 years	2.26	(1.92, 2.67)	2.41	(1.86, 3.13)	2.33	(2.03, 2.67)
≥60 years	11.96	(8.80, 16.26)	8.29	(2.59, 26.56)	11.46	(8.58, 15.30)
p-trend	0.1931		0.1400		0.1891	
Life course residence**						
Rural-rural (RR)	1.00		1.00		1.00	
Rural-urban (RU)	0.86	(0.74, 1.00)	0.79	(0.62, 1.00)	0.84	(0.74, 0.95)
Urban-rural (UR)	1.26	(0.98, 1.62)	0.98	(0.64, 1.51)	1.19	(0.95, 1.48)
Urban-urban (UU)	0.94	(0.79, 1.13)	1.17	(0.93, 1.49)	1.04	(0.91, 1.20)
Education level						
Junior school	1.00		1.00		1.00	
High school	0.76	(0.60, 0.96)	1.02	(0.59, 1.76)	0.81	(0.66, 1.00)
Diploma	0.81	(0.64, 1.04)	0.92	(0.53, 1.60)	0.83	(0.66, 1.03)
University	0.72	(0.56, 0.93)	0.64	(0.36, 1.12)	0.68	(0.55, 0.86)
p-trend	0.1770		0.1315		0.0765	
Personal monthly income (baht)						
≤ 7,000 baht	1.00		1.00		1.00	
7,001–10,000 baht	1.03	(0.87, 1.22)	1.06	(0.83, 1.36)	1.05	(0.91, 1.21)
10,001–20,000 baht	0.82	(0.68, 0.98)	1.20	(0.93, 1.55)	0.92	(0.80, 1.07)
≥ 20,001 baht	0.73	(0.59, 0.92)	0.99	(0.69, 1.42)	0.80	(0.66, 0.97)
p-trend	0.0966		0.7921		0.0598	
Health behaviours/Personal lifestyles						
Diet consumptions						
Soybean products						
Never	1.00		1.00		1.00	
1–3 times/month	0.89	(0.74, 1.07)	0.72	(0.52, 0.99)	0.85	(0.72, 0.99)
1–2 times/week	0.97	(0.81, 1.16)	1.02	(0.76, 1.37)	0.99	(0.85, 1.16)
3–6 times/week	0.94	(0.77, 1.15)	1.07	(0.79, 1.44)	0.99	(0.84, 1.16)
Daily or more	1.03	(0.80, 1.32)	0.97	(0.69, 1.35)	1.00	(0.83, 1.22)
p-trend	0.5980		0.5815		0.5752	
Activity status						
Housework						
Never	1.00		1.00		1.00	
1–3 times/month	1.03	(0.79, 1.34)	0.80	(0.49, 1.28)	0.98	(0.78, 1.24)
Once or twice/week	1.03	(0.81, 1.31)	0.73	(0.48, 1.10)	0.97	(0.79, 1.20)
3–4 times/week	1.01	(0.77, 1.33)	0.71	(0.45, 1.12)	0.95	(0.75, 1.20)
Every day or more	1.21	(0.96, 1.53)	0.69	(0.46, 1.04)	1.07	(0.87, 1.31)
p-trend	0.1645		0.0450		0.5318	

(Continued on following page)

TABLE 1 | (Continued) Multivariate adjusted hazard ratios according to multimorbidity, the number of chronic conditions (CC) and risk factors (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Participants						
	Male		Female		Total	
	AHR*	(95% CI)	AHR*	(95% CI)	AHR*	(95% CI)
Sleeping time (hours)						
≤6 h	1.06	(0.93, 1.21)	0.99	(0.81, 1.21)	1.04	(0.94, 1.17)
7–8 h	1.00		1.00		1.00	
≥9 h	1.25	(1.04, 1.49)	1.24	(0.96, 1.60)	1.25	(1.08, 1.44)
p-trend	0.4810		0.3108		0.4285	
Smoking and Drinking status						
Smoking						
Never smoking	1.00		1.00		1.00	
Smoking	1.45	(1.26, 1.66)	1.29	(0.92, 1.80)	1.41	(1.24, 1.60)
Drinking						
Never	1.00		1.00		1.00	
Ex-drinker	1.26	(1.02, 1.57)	1.11	(0.91, 1.35)	1.17	(1.01, 1.35)
Occasional or social	1.37	(1.15, 1.65)	1.79	(0.83, 3.86)	1.37	(1.15, 1.63)
Current regular	1.41	(1.19, 1.67)	1.57	(1.16, 2.13)	1.44	(1.25, 1.67)
p-trend	0.0627		0.1762		0.0160	

AHR*: Multivariate adjusted Hazard ratios from Cox proportional hazard models controlling for other socio-demographic factors and personal lifestyle elements (variables in **Supplementary Table S2 in Supplementary File S1**). AHR bolding: The results of AHR were statistical significance ($p < 0.05$). p-trend bolding: The results of p-trend were statistical significance (p for trend < 0.05). Life course residence**: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) [16, 19, 21, 22].



DISCUSSION

Our findings suggest that multimorbidity as an independent risk factor reduces the chances of survival and increases the risk of death in this study, over 15 years of follow-up. The higher the number of diseases suffered by participants, the lower the chances of survival. Across age groups, the risk of death for those with

multimorbidity increased and the chance of survival decreases with increasing age. Compared to young people without multimorbidity, the older the person is, the higher the risk of death if they have multimorbidity at the same time. In addition, male sex, sleeping longer, smoking and drinking alcohol were risk factors for death, while female sex, urbanizing, university graduate status, high personal monthly income (more than

TABLE 2 | Hazard ratios according to number of multimorbidity or chronic conditions, and age (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Participants								
	Univariate hazard ratios (HRs) (95% CI)				Multivariate adjusted hazard ratios (AHRs*) (95% CI)			
	Age groups				Age groups			
	≤39 years old	40–59 years old	≥60 years old	p-trend	≤39 years old	40–59 years old	≥60 years old	p-trend
Multimorbidity								
No	1.00	1.00	1.00	NA	1.00	1.00	1.00	NA
Yes	1.80 (1.54, 2.10)	1.45 (1.23, 1.71)	1.27 (0.84, 1.93)	0.1302	1.49 (1.25, 1.77)	1.37 (1.14, 1.66)	3.02 (1.43, 6.44)	0.3545
Number of chronic conditions (CC)								
0 CC	1.00	1.00	1.00	NA	1.00	1.00	1.00	NA
1 CC	1.40 (1.24, 1.58)	1.46 (1.19, 1.79)	1.3 (0.70, 2.39)	0.5618	1.26 (1.09, 1.44)	1.59 (1.25, 2.01)	1.19 (0.41, 3.49)	0.8868
2 CC	1.86 (1.54, 2.25)	1.58 (1.25, 1.99)	1.56 (0.86, 2.86)	0.3090	1.50 (1.21, 1.85)	1.60 (1.22, 2.11)	3.76 (1.35, 10.52)	0.2868
3 CC	2.47 (1.79, 3.41)	1.98 (1.47, 2.67)	1.13 (0.50, 2.54)	0.0844	2.09 (1.48, 2.95)	2.06 (1.47, 2.89)	3.54 (1.04, 12.11)	0.3217
≥4 CC	2.37 (1.39, 4.01)	2.43 (1.70, 3.48)	1.73 (0.76, 4.00)	0.3690	1.63 (0.87, 3.06)	2.25 (1.48, 3.41)	2.25 (0.60, 8.47)	0.3566
p-trend	0.0096	0.0018	0.2082	NA	0.0980	0.0070	0.2885	NA

NA: Not available. AHRs*: Multivariate adjusted Hazard ratios from Cox proportional hazard models controlling for other socio-demographic factors and personal lifestyle elements (variables in **Supplementary Table S2** in **Supplementary File S1**). AHRs bolding: The results of Multivariate hazard ratios (HR) were statistical significance ($p < 0.05$). p-trend bolding: The results of p-trend were statistical significance (p for trend < 0.05).

20,000 baht) and consuming soybean products were protective factors. Furthermore, when people suffering from multimorbidity, also have abnormal sleeping time, smoke and drink alcohol the risk of death further increases, whereas high socio-economic status (SES) (university graduate status and more than 20,000 baht monthly) could reduce the risk of death.

Age is the most important factor driving multimorbidity. Like the results of other studies [8], the older the person was the higher their risk of death if also having multimorbidity. This may be related to the fact that as age increased, the chances of developing multimorbidity increased, thus raising the risk of death, and that age itself is an independent risk factor for death [1, 2]. However, the aging of Thai society is getting serious. In 2020, about one-fifth of the population were over 60 years old, and this proportion will increase to about 30% in 2030 [24]. Therefore, how to delay the development of age-related health conditions in the society and improve the health of the elderly is particularly important for Thailand [13].

In terms of gender, we found that women participants appear to be more likely to survive than men regardless of these females with or without multimorbidity, which is similar to the findings of a European study [1]. This may be due to genetic differences between males and females [25], unmeasured confounders such as differences in health-seeking behaviours between men and women [25], and males would be susceptible to diseases with higher mortality rates, whereas females are more likely to suffer from chronic diseases with higher rates of disability [26], all of which may make females less exposed to the risk of death. Therefore, incorporating gender perspectives into health interventions is essential. It is worth noting, however, that Thai women in general may experience more health inequalities because their social welfare indicators still lag behind those of Thai men [27].

The risk of death was also lower among those with university-level education, and/or those with a monthly income of over 20,000 baht, which is consistent with the

findings of a study examining the relationship between socio-economic inequality and mortality, that is, the risk of death was lower among those with high income and/or high education compared to people with low income and/or low education [28]. People who move from rural to urban areas (urbanizers) also have a lower risk of death compared to those who are lifelong living in rural places, and such results are similar to those of a US study [29]. Also, high-income and highly educated people, namely, those with high SES who suffer from multimorbidity, also have a lower risk of death than healthy people with low SES. This outcome is similar to the findings of the Danish [30] and Canadian studies [31]. As this illustrates, people of higher SES have a lower risk of mortality since they have more financial and material resources to maintain a healthy life, to reduce the incidence of accidents, and to prevent and treat diseases more effectively [28–31].

People who sleep more than 9 h per day also had an increased risk of death compared to those who had a standard sleep duration (6–8 h), and such results were consistent with the findings of a systematic review on sleep duration and mortality [32]. In addition, for people with multimorbidity, abnormal sleep duration can also cause an increased risk of death, and they have a greater risk of death than people with multimorbidity who have a normal sleep duration. Such results are similar to the findings of a Chinese study on sleep duration and multimorbidity [33]. Thus, excessive or short sleep duration may increase the risk of death, which may be due to the fact that sleeping too long or too short may cause damage to the endocrine system and metabolism, which may lead to a range of diseases, including hypertension and diabetes, which may cause or exacerbate multimorbidity, then leading to death [32, 33]. It is also important to note that not only does sleep duration have an impact on chronic conditions, but chronic diseases also affect sleep duration because patients with multimorbidity may also have abnormal sleep duration due to their conditions such as pain

TABLE 3 | Multivariate adjusted hazard ratios according to the interaction between multimorbidity and risk factors (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Participants	Male		Female		Total	
	AHR*	(95% CI)	AHR*	(95% CI)	AHR*	(95% CI)
Socio-demographic factors						
Multimorbidity*gender (References: no multimorbidity*male) having multimorbidity	1.32	(1.14, 1.52)	0.94	(0.74, 1.19)		
Multimorbidity*age (years) (References: no multimorbidity*≤39 years)						
Having multimorbidity*≤39 years	1.40	(1.13, 1.73)	1.83	(1.34, 2.51)	1.51	(1.27, 1.80)
Having multimorbidity*40–59 years	3.11	(2.52, 3.84)	4.06	(2.78, 5.95)	3.27	(2.72, 3.93)
Having multimorbidity*≥60 years	17.03	(11.59, 25.03)	26.53	(8.20, 85.81)	17.41	(12.14, 24.97)
p-trend	0.0421		0.0837		0.0413	
Socio-economic status (SES)						
Multimorbidity*Personal monthly income (baht)*Education level (References: no multimorbidity*≤ 7,000 baht*junior school)						
Having multimorbidity*≥20,001 baht*junior school	0.70	(0.32, 1.53)	1.91	(0.38, 9.73)	0.81	(0.40, 1.62)
Having multimorbidity*≥20,001 baht*high school	0.39	(0.22, 0.69)	0.82	(0.23, 2.97)	0.43	(0.26, 0.72)
Having multimorbidity*≥20,001 baht*diploma	0.58	(0.33, 1.02)	0.92	(0.26, 3.33)	0.61	(0.37, 1.03)
Having multimorbidity*≥20,001 baht*university	0.50	(0.31, 0.79)	0.46	(0.14, 1.54)	0.49	(0.32, 0.75)
p-trend	0.4263		0.0253		0.1948	
Health behaviours/Personal lifestyles						
Activity status						
Multimorbidity*Sleeping time (hours) (References: no multimorbidity*7–8 h)						
Having multimorbidity*≤6 h	1.48	(1.20, 1.84)	1.69	(1.14, 2.51)	1.51	(1.25, 1.83)
Having multimorbidity*7–8 h	1.25	(1.02, 1.53)	1.61	(1.14, 2.28)	1.31	(1.10, 1.57)
Having multimorbidity*≥ 9 h	1.81	(1.31, 2.52)	2.82	(1.64, 4.86)	2.01	(1.52, 2.66)
p-trend	0.6013		0.3710		0.5122	
Smoking and drinking status						
Multimorbidity*Smoking (References: no multimorbidity*never smoking)						
Having multimorbidity*never smoking	1.57	(1.21, 2.02)	1.75	(1.35, 2.28)	1.68	(1.40, 2.01)
Having multimorbidity*smoking	2.12	(1.73, 2.58)	2.39	(1.29, 4.42)	2.05	(1.71, 2.46)
Multimorbidity*Drinking (References: no multimorbidity*never)						
Having multimorbidity*never	1.36	(1.13, 1.64)	1.81	(1.28, 2.58)	1.43	(1.21, 1.68)
Having multimorbidity*ex-drinker	2.19	(1.48, 3.24)	1.86	(1.26, 2.75)	2.03	(1.54, 2.66)
Having multimorbidity* occasional or social	1.70	(1.25, 2.32)	0.00		1.65	(1.21, 2.24)
Having multimorbidity*current regular	1.87	(1.41, 2.49)	3.33	(1.89, 5.89)	2.02	(1.57, 2.60)
p-trend	0.7108		0.7443		0.3898	

AHRs*: Multivariate adjusted Hazard ratios from Cox proportional hazard models controlling for other socio-demographic factors and personal lifestyle elements (variables in **Supplementary Table S2** in **Supplementary File S1**). AHRs bolding: The results of Multivariate hazard ratios (HR) were statistical significance ($p < 0.05$). p-trend bolding: The results of p-trend were statistical significance (p for trend < 0.05).

and weakness [32, 33]. Thus, multimorbidity and sleep time abnormalities can act either independently or interact to increase the risk of death [32, 33].

Although we could not find the significant results of the interaction between the intake of soybeans and multimorbidity, the consumption of soybean products, as the independent variable, could decrease the risk of death in our study, which is consistent with a study in China [34]. This is because soy consumption lowers cholesterol and thus reduces the risk of cardiovascular diseases (CVDs), which is the main cause of disability-adjusted life years (DALYs) lost worldwide [34]. Furthermore, similarly, while in our study, the interaction between multimorbidity and frequency of housework resulted in a statistically insignificant effect on all-cause mortality. However, when frequency of housework was used as an independent variable, for women, more frequent housework

was inversely linear associated with the risk of death, which is similar to the findings of a study in China that found that housework reduced the risk of death from diseases related to cancer [35]. In our findings, smoking [2, 3, 36] and alcohol consumption [2, 7, 36] increased the risk of death in the population with or without multimorbidity, which is consistent with most studies [2, 3, 7, 36]. The increased risk of death due to smoking and alcohol consumption may be due to cardiovascular diseases and related cancers, such as liver and lung cancers [34], which may predispose to or aggravate chronic conditions [36, 37].

Strengths and Limitations

This study is a 15 years study and with over 80,000 participants and 1,958 death cases, the sample size is very large and rich. It is also the first study to use the TCS to examine multimorbidity (and

to divide it into different numbers of diseases) and mortality, and their associated risk factors. The other strength is also that it uses official Thai government mortality data, which has a high degree of veracity [13].

However, the study also has limitations. The age distribution of cohort members was generally younger and cohort members were more highly educated than the general population. In addition, all variables except mortality status are self-reported and therefore subject to some measurement error and or recall bias [13, 23].

Since the cause of death was not presented, this study used all-cause mortality as the primary outcome, which means that it would have some limitations in connecting multimorbidity to risk of cause-specific of death. However, this measure would have some advantages in terms of being able to see the big picture risks associated with multimorbidity, which has the potential to be diluted through breaking up the deaths into multiple specific causes. Future analysis in this cohort study will focus on causes of death.

Further Research

Therefore, in further studies, the focus should be on investigating the causes of death in the cohort study and will begin to establish potential causal relationships between identified risk factors and causes of death, particularly in relation to multimorbidity [15, 23]. Additionally, more attention should also be paid to the issue of ageing in Thailand and to increasing research into the prevention and treatment of multimorbidity in collaboration with the local Thai government [13].

Conclusion

In the study, which lasted 15 years, multimorbidity and a higher number of co-existing diseases, age, long sleep duration, smoking and alcohol consumption were all independent factors that increased the risk of death. On the other hand, women, moving to urban places, high monthly income, university degrees and intake of soybean food may have reduced their risk of death. Moreover, in addition to gender, life course residence and the consumption of soybean products, the interaction between multimorbidity and these variables would also have a significant effect on all-cause mortality. It is hoped that these findings would help people to take their health seriously and that the authorities would strengthen the control and intervention of multimorbidity to improve the quality of life of people.

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ETHICS STATEMENT

The studies involving humans were approved by the ethics committee of the Sukhothai Thammathirat Open University Research and Development Institute (protocol number: 0522/10). For this sub-sample analysis, we also got approval from Human Research Ethics Committee of the Australian National University (protocol number: 2004/344, 2009/570, 2021/796). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

XF conceived the study. XF designed the study. S-AS, AS, and MK provided the database. XF analyzed and interpreted the data and drafted the manuscript. HS and MK revised the manuscript for intellectual content. XF and MK are the guarantors of the paper. All authors contributed to the article and approved the submitted version.

CONFLICT OF INTEREST

The authors declare that they do not have any conflicts of interest.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.ssph-journal.org/articles/10.3389/ijph.2023.1606137/full#supplementary-material>

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The impact of multimorbidity on all-cause mortality: A longitudinal study of 87151 Thai adults

Supplementary Table 1: Cohort characteristics by survival status (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Factors	Male				Female				Total			
	Alive N (%)	Dead N (%)	All N (%)	CMR per 1000*	Alive N (%)	Dead N (%)	All N (%)	CMR per 1000*	Alive N (%)	Dead N (%)	All N (%)	CMR per 1000*
Participants	38123 (44.75)	1362 (69.56)	39,485 (45.28)	34.50	47,062 (55.25)	596 (30.44)	47,658 (54.69)	12.51	85,185 (100.00)	1,958 (100.00)	87,143 (100.00)	22.47
p-value	p<0.0001											
Multimorbidity												
No	32113 (84.24)	1011 (74.23)	33124 (83.89)	30.52	43237 (91.87)	492 (82.55)	43729 (91.76)	11.25	75350 (88.45)	1503 (76.76)	76853 (88.20)	19.56
Yes	6010 (15.76)	351 (25.77)	6361 (16.11)	55.18	3825 (8.13)	104 (17.45)	3929 (8.24)	26.47	9835 (11.55)	455 (23.24)	10290 (11.81)	44.22
p-value	p<0.0001											
Number of chronic conditions (CC)												
0 CC	20725 (54.36)	569 (41.78)	21294 (53.93)	26.72	31461 (66.85)	299 (50.17)	31760 (66.64)	9.41	52186 (61.26)	868 (44.33)	53054 (60.88)	16.36
1 CC	11388 (29.87)	442 (32.45)	11830 (29.96)	37.36	11776 (25.02)	193 (32.38)	11969 (25.11)	16.12	23164 (27.19)	635 (32.431)	23799 (27.31)	26.68
2 CC	4165 (10.93)	217 (15.93)	4382 (11.098)	49.52	2912 (6.19)	71 (11.91)	2983 (6.26)	23.80	7077 (8.31)	288 (14.71)	7365 (8.45)	39.1
3 CC	1273 (3.34)	86 (6.31)	1359 (3.44)	63.28	655 (1.39)	22 (3.69)	677 (1.42)	32.50	1928 (2.26)	108 (5.52)	2036 (2.34)	53.05
≥ 4 CC	572 (1.50)	48 (3.52)	620 (1.57)	77.42	258 (0.55)	11 (1.85)	269 (0.56)	40.89	830 (0.97)	59 (3.01)	889 (1.02)	66.37
p-value	p<0.0001											
Age (years) means (SD)												
	32.04 (8.58)	37.75 (12.14)	32.24 (16.81)		29.01 (7.48)	32.81 (9.23)	29.06 (7.51)		30.37 (8.13)	36.25 (11.56)	30.51 (8.27)	
Age groups (years)												
≤ 39 years	30661 (80.44)	810 (59.47)	31471 (79.71)	25.74	42113 (89.50)	450 (75.5)	42563 (89.32)	10.57	72774 (85.44)	1260 (85.44)	74034 (64.35)	17.02
40-59 years	7268 (19.04)	468 (34.36)	7736 (19.6)	60.5	4902 (10.42)	142 (23.823)	5044 (10.59)	28.15	12170 (14.29)	610 (14.29)	12780 (31.15)	47.73

≥ 60 years	189 (0.50)	84 (6.17)	273 (0.69)	307.7	41 (0.08)	4 (0.67)	45 (0.09)	88.89	230 (0.27)	88 (0.27)	318 (4.49)	276.73
p-value				p<0.0001				p<0.0001				p<0.0001
Marital status												
Single	17422 (47.05)	519 (39.77)	17941 (46.8)	28.93	27231 (59.61)	308 (53.94)	27539 (59.54)	11.18	44653 (53.99)	827 (44.08)	45480 (53.77)	18.18
Living with partner	1933 (5.22)	56 (4.29)	1989 (5.19)	28.15	2338 (5.12)	28 (4.9)	2366 (5.12)	11.83	4271 (5.16)	84 (4.48)	4355 (5.15)	19.29
Married	17673 (47.73)	730 (55.94)	18403 (48.01)	39.67	16112 (35.27)	235 (41.16)	16347 (35.34)	14.38	33785 (40.85)	965 (51.44)	34750 (41.08)	27.77
p-value				p<0.0001				p=0.0130				p<0.0001
Geographic Regions												
Bangkok	5522 (14.62)	193 (14.31)	5715 (14.61)	33.77	9028 (19.32)	120 (20.27)	9148 (19.41)	13.12	14550 (17.22)	313 (16.13)	14863 (17.19)	21.06
Central	8582 (22.72)	285 (21.13)	8867 (22.66)	32.14	12145 (25.99)	154 (26.01)	12299 (26.09)	12.52	20727 (24.53)	439 (22.62)	21166 (24.49)	20.74
North	7391 (19.57)	268 (19.87)	7659 (19.58)	34.99	7987 (17.09)	108 (18.24)	8095 (17.17)	13.34	15378 (18.20)	376 (19.37)	15754 (18.22)	23.87
Northeast	9207 (24.37)	347 (25.72)	9554 (24.42)	36.32	8382 (17.94)	102 (17.23)	8484 (18.00)	12.02	17589 (20.82)	449 (23.13)	18038 (20.87)	24.89
East	2312 (6.12)	85 (6.30)	2397 (6.13)	35.46	2898 (6.20)	32 (5.41)	2,930 (6.22)	10.92	5,210 (6.17)	117 (6.03)	5,327 (6.16)	21.96
South	4,762 (12.61)	171 (12.68)	4,933 (12.61)	34.66	6,285 (13.45)	76 (12.84)	6,361 (13.49)	11.95	11,047 (13.07)	247 (12.73)	11,294 (13.07)	21.87
p-value				p=0.7540				p=0.8950				p=0.0580
Life course residence**												
Rural-rural (RR)	17,012 (45.27)	595 (45.04)	17607 (45.26)	33.79	19,899 (42.75)	238 (40.55)	20137 (42.72)	11.82	36,911 (43.88)	833 (43.69)	37744 (43.87)	22.07
Rural-urban (RU)	12,227 (32.53)	392 (29.67)	12619 (32.44)	31.06	14,657 (31.49)	157 (26.75)	14814 (31.43)	10.6	26,884 (31.95)	549 (28.77)	27433 (31.89)	20.01
Urban-rural (UR)	1,621 (4.31)	78 (5.90)	1699 (4.37)	45.91	1,981 (4.26)	27 (4.60)	2008 (4.26)	13.45	3,602 (4.28)	105 (5.50)	3707 (4.31)	28.32
Urban-urban (UU)	6,722 (17.89)	256 (19.38)	6978 (17.94)	36.67	10,008 (21.50)	165 (28.11)	10173 (21.58)	16.22	16,730 (19.89)	421 (22.06)	17151 (19.93)	24.55
p-value				p=0.0010				p=0.0070				p=0.001
Education level												
Junior school	1845 (4.85)	126 (9.29)	1971 (5.00)	63.93	1049 (2.24)	19 (3.19)	1068 (2.25)	17.79	2894 (3.41)	145 (7.43)	3039 (3.50)	47.71
High school	19115 (50.27)	664 (48.93)	19779 (50.22)	33.57	19365 (41.27)	270 (45.38)	19635 (41.32)	13.75	38480 (45.3)	934 (47.85)	39414 (45.35)	23.7
Diploma	8609 (22.64)	294 (21.67)	8903 (22.61)	33.02	14384 (30.65)	181 (30.42)	14565 (30.655)	12.43	22993 (27.07)	475 (24.34)	23468 (27.00)	20.24
University	8459 (22.24)	273 (20.12)	8732 (22.17)	31.26	12128 (25.84)	125 (21.01)	12253 (25.78)	10.2	20587 (24.22)	398 (20.39)	20985 (24.15)	18.97
p-value				p<0.0001				p=0.0170				p<0.0001
Personal monthly income (baht)												
≤ 7000 baht	13166 (35.39)	443 (34.05)	13609 (35.35)	32.55	21775 (47.47)	251 (43.2)	22026 (47.41)	11.40	34941 (42.06)	694 (36.88)	35635 (41.94)	19.48
7001-10000 baht	8539 (22.95)	282 (21.68)	8821 (22.91)	31.97	10860 (23.67)	117 (20.14)	10977 (23.63)	10.66	19399 (23.35)	399 (21.20)	19798 (23.30)	20.15

10001-20000 baht	10561 (28.39)	360 (27.67)	10921 (28.36)	32.96	9503 (20.72)	145 (24.96)	9648 (20.77)	15.03	20064 (24.15)	505 (26.83)	20569 (24.21)	24.55
≥ 20001 baht	4936 (13.27)	216 (16.60)	5152 (13.38)	41.93	3735 (8.14)	68 (11.70)	3803 (8.19)	17.88	8671 (10.44)	284 (15.09)	8955 (10.54)	31.71
p-value				p=0.0010				p<0.0001				p<0.0001

CMR per 1000*: 15-year cumulative mortality probability per 1000.
Life course residence**: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) (16, 19, 21, 22).

Supplementary Table 2: Univariate hazard ratios (HRs) according to multimorbidity, number of chronic conditions (CC) and risk factors (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Participants								
	Male			Female			Total	
	HR	(95 % CI)		HR	(95 % CI)		HR	(95 % CI)
Two or more chronic conditions								
Multimorbidity								
No	1.00			1.00			1.00	
Yes	1.83	(1.62, 2.06)		2.37	(1.92, 2.93)		2.29	(2.06, 2.54)
Number of chronic conditions (CC)								
0 CC	1.00			1.00			1.00	
1 CC	1.41	(1.24, 1.59)		1.72	(1.43, 2.06)		1.64	(1.48, 1.82)
2 CC	1.87	(1.60, 2.19)		2.55	(1.97, 3.30)		2.41	(2.11, 2.76)
3 CC	2.40	(1.92, 3.01)		3.49	(2.26, 5.38)		3.29	(2.70, 4.02)
≥ 4 CC	2.97	(2.21, 3.98)		4.38	(2.40, 8.00)		4.15	(3.19, 5.40)
p-trend	0.0001			0.0001			0.0001	
Socio-demographic factors								
Gender	1.00			0.36	(0.33, 0.40)			
Age (years)								
≤ 39 years	1.00			1.00			1.00	
40-59 years	2.39	(2.13, 2.67)		2.68	(2.22, 3.24)		2.84	(2.58, 3.13)
≥ 60 years	13.79	(11.02, 17.27)		8.61	(3.22, 23.05)		18.47	(14.88, 22.93)
p-trend	0.1972			0.1220			0.2520	
Marital status								
Single	1.00			1.00			1.00	
Living with partner	0.97	(0.74, 1.28)		1.06	(0.72, 1.56)		1.06	(0.85, 1.33)
Married	1.38	(1.23, 1.54)		1.29	(1.09, 1.52)		1.53	(1.40, 1.68)
Geographic regions								
Bangkok	1.00			1.00			1.00	
Central	0.95	(0.79, 1.14)		0.95	(0.75, 1.21)		0.98	(0.85, 1.14)
North	1.04	(0.86, 1.25)		1.02	(0.78, 1.32)		1.13	(0.98, 1.32)
Northeast	1.08	(0.90, 1.28)		0.92	(0.70, 1.19)		1.18	(1.02, 1.37)

East	1.05	(0.81, 1.36)	0.83	(0.56, 1.23)	1.04	(0.84, 1.29)
South	1.03	(0.84, 1.26)	0.91	(0.68, 1.21)	1.04	(0.88, 1.23)
Life course residence*						
Rural-rural (RR)	1.00		1.00		1.00	
Rural-urban (RU)	0.92	(0.81, 1.04)	0.90	(0.73, 1.10)	0.91	(0.81, 1.01)
Urban-rural (UR)	1.37	(1.08, 1.73)	1.14	(0.76, 1.70)	1.29	(1.05, 1.58)
Urban-urban (UU)	1.08	(0.94, 1.26)	1.38	(1.13, 1.68)	1.11	(0.99, 1.25)
Education level						
Junior school	1.00		1.00		1.00	
High school	0.52	(0.43, 0.63)	0.77	(0.49, 1.23)	0.49	(0.41, 0.58)
Diploma	0.51	(0.41, 0.63)	0.70	(0.44, 1.12)	0.42	(0.35, 0.50)
University	0.48	(0.39, 0.59)	0.57	(0.35, 0.93)	0.39	(0.32, 0.47)
p-trend	0.1891		0.0243		0.1436	
Personal monthly income (baht)						
≤ 7000 baht	1.00		1.00		1.00	
7001-10000 baht	0.98	(0.84, 1.14)	0.93	(0.75, 1.16)	1.03	(0.91, 1.17)
10001-20000 baht	1.01	(0.88, 1.16)	1.32	(1.08, 1.62)	1.26	(1.13, 1.42)
≥ 20001 baht	1.29	(1.10, 1.52)	1.57	(1.20, 2.05)	1.64	(1.42, 1.88)
p-trend	0.0380		0.0650		0.0077	
Health behaviours/ Personal lifestyles						
Diet consumptions						
Deep fried food						
Never	1.00		1.00		1.00	
1-3 times/month	0.66	(0.49, 0.89)	0.63	(0.41, 0.98)	0.63	(0.50, 0.81)
1-2 times/week	0.54	(0.41, 0.71)	0.66	(0.43, 1.00)	0.58	(0.46, 0.73)
3-6 times/week	0.53	(0.40, 0.70)	0.54	(0.35, 0.82)	0.56	(0.44, 0.70)
Daily or more	0.52	(0.39, 0.70)	0.50	(0.32, 0.78)	0.53	(0.41, 0.68)
p-trend	0.0716		0.0531		0.0854	
Instant food						
Never	1.00		1.00		1.00	
1-3 times/month	0.68	(0.59, 0.78)	0.74	(0.60, 0.92)	0.67	(0.59, 0.75)
1-2 times/week	0.67	(0.58, 0.78)	0.69	(0.54, 0.87)	0.66	(0.58, 0.75)
3-6 times/week	0.70	(0.58, 0.83)	0.74	(0.56, 0.98)	0.70	(0.60, 0.81)

Daily or more	0.57	(0.39, 0.83)	0.65	(0.38, 1.11)	0.56	(0.41, 0.77)
p-trend	0.0910		0.0967		0.0975	
Soft drink						
Never	1.00		1.00		1.00	
1-3 times/month	0.81	(0.70, 0.94)	0.78	(0.63, 0.97)	0.88	(0.77, 0.99)
1-2 times/week	0.73	(0.63, 0.85)	0.76	(0.60, 0.96)	0.86	(0.76, 0.98)
3-6 times/week	0.73	(0.62, 0.87)	0.97	(0.76, 1.24)	0.95	(0.83, 1.09)
Daily or more	0.72	(0.57, 0.91)	0.97	(0.71, 1.32)	0.88	(0.73, 1.06)
p-trend	0.0679		0.7935		0.4406	
Soybean products						
Never	1.00		1.00		1.00	
1-3 times/month	0.83	(0.71, 0.98)	0.80	(0.59, 1.08)	0.80	(0.69, 0.92)
1-2 times/week	0.89	(0.76, 1.05)	1.02	(0.77, 1.35)	0.85	(0.74, 0.98)
3-6 times/week	0.94	(0.80, 1.12)	1.06	(0.80, 1.40)	0.85	(0.73, 0.98)
Daily or more	1.03	(0.83, 1.29)	1.07	(0.79, 1.46)	0.81	(0.68, 0.96)
p-trend	0.5643		0.3128		0.2364	
Vegetable (serves/day)						
0-4	1.00		1.00		1.00	
5-9	1.07	(0.84, 1.37)	0.68	(0.43, 1.08)	0.96	(0.77, 1.19)
10-14	0.82	(0.51, 1.33)	1.23	(0.66, 2.29)	0.97	(0.66, 1.42)
≥ 15	1.80	(1.02, 3.18)	0.36	(0.05, 2.57)	1.41	(0.82, 2.43)
p-trend	0.2120		0.4047		0.1327	
Fruit (serves/day)						
0-4	1.00		1.00		1.00	
5-9	0.95	(0.80, 1.13)	0.90	(0.71, 1.14)	0.86	(0.75, 0.99)
10-14	1.04	(0.80, 1.35)	0.77	(0.51, 1.16)	0.89	(0.71, 1.11)
≥ 15	1.42	(0.93, 2.17)	0.67	(0.30, 1.51)	1.07	(0.74, 1.56)
p-trend	0.0841		0.0406		0.4517	
Activity status						
Weekly exercise (sessions)#						
0-7	1.00		1.00		1.00	
8-14	0.89	(0.78, 1.01)	0.99	(0.82, 1.20)	1.08	(0.97, 1.20)
≥ 15	0.95	(0.84, 1.08)	1.16	(0.92, 1.45)	1.32	(1.18, 1.47)
p-trend	0.7514		0.2735		0.0877	

Housework							
Never	1.00		1.00		1.00		
1-3 times/month	0.89	(0.71, 1.12)	0.84	(0.54, 1.30)	0.85	(0.69, 1.04)	
Once or twice/week	0.81	(0.66, 1.00)	0.69	(0.47, 1.01)	0.67	(0.56, 0.81)	
3-4 times/week	0.81	(0.64, 1.02)	0.64	(0.41, 0.98)	0.67	(0.54, 0.82)	
Every day or more	1.20	(0.99, 1.46)	0.70	(0.49, 1.02)	0.79	(0.67, 0.94)	
p-trend	0.6186		0.0665		0.2002		
Sleeping time (hours)							
≤ 6 hours	1.20	(1.07, 1.35)	1.00	(0.83, 1.20)	1.17	(1.06, 1.29)	
7-8 hours	1.00		1.00		1.00		
≥ 9 hours	1.25	(1.06, 1.47)	1.17	(0.93, 1.47)	1.19	(1.04, 1.36)	
p-trend	0.8852		0.3176		0.9389		
Sedentary time (hours)							
≤ 7 hours	1.00		1.00		1.00		
8-12 hours	0.88	(0.78, 0.99)	1.19	(0.99, 1.45)	0.90	(0.81, 1.00)	
≥ 13 hours	0.84	(0.73, 0.97)	1.11	(0.90, 1.36)	0.80	(0.72, 0.90)	
p-trend	0.1960		0.6231		0.0051		
Smoking and Drinking status							
Smoking							
Never smoking	1.00		1.00		1.00		
Smoking	1.79	(1.59, 2.00)	1.50	1.11, 2.01)	2.58	(2.36, 2.82)	
Drinking							
Never	1.00		1.00		1.00		
Ex-drinker	1.12	(0.94, 1.35)	1.16	(0.97, 1.37)	0.81	(0.72, 0.91)	
Occasional or social	1.62	(1.37, 1.90)	2.31	(1.14, 4.67)	2.22	(1.90, 2.59)	
Current regular	2.03	(1.76, 2.34)	1.61	(1.22, 2.13)	2.02	(1.78, 2.29)	
p-trend	0.0232		0.3420		0.3420		

p-trend **bolding**: The results of p-trend were statistical significance.

Life course residence*: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) (16, 19, 21, 22).

Weekly exercise#: The Combined measure of weekly physical activities: “2 × vigorous exercises + 1 × moderate exercises + 1 × walking sessions per week”, which was on the basis of International Physical Activity Questionnaire and the Active Australia Survey (21, 22).

The impact of multimorbidity on all-cause mortality: A longitudinal study of 87151 Thai adults

Supplementary Table 1: Cohort characteristics by survival status (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Factors	Male				Female				Total			
	Alive N (%)	Dead N (%)	All N (%)	CMR per 1000*	Alive N (%)	Dead N (%)	All N (%)	CMR per 1000*	Alive N (%)	Dead N (%)	All N (%)	CMR per 1000*
Participants	38123 (44.75)	1362 (69.56)	39,485 (45.28)	34.50	47,062 (55.25)	596 (30.44)	47,658 (54.69)	12.51	85,185 (100.00)	1,958 (100.00)	87,143 (100.00)	22.47
p-value	p<0.0001											
Multimorbidity												
No	32113 (84.24)	1011 (74.23)	33124 (83.89)	30.52	43237 (91.87)	492 (82.55)	43729 (91.76)	11.25	75350 (88.45)	1503 (76.76)	76853 (88.20)	19.56
Yes	6010 (15.76)	351 (25.77)	6361 (16.11)	55.18	3825 (8.13)	104 (17.45)	3929 (8.24)	26.47	9835 (11.55)	455 (23.24)	10290 (11.81)	44.22
p-value	p<0.0001											
Number of chronic conditions (CC)												
0 CC	20725 (54.36)	569 (41.78)	21294 (53.93)	26.72	31461 (66.85)	299 (50.17)	31760 (66.64)	9.41	52186 (61.26)	868 (44.33)	53054 (60.88)	16.36
1 CC	11388 (29.87)	442 (32.45)	11830 (29.96)	37.36	11776 (25.02)	193 (32.38)	11969 (25.11)	16.12	23164 (27.19)	635 (32.431)	23799 (27.31)	26.68
2 CC	4165 (10.93)	217 (15.93)	4382 (11.098)	49.52	2912 (6.19)	71 (11.91)	2983 (6.26)	23.80	7077 (8.31)	288 (14.71)	7365 (8.45)	39.1
3 CC	1273 (3.34)	86 (6.31)	1359 (3.44)	63.28	655 (1.39)	22 (3.69)	677 (1.42)	32.50	1928 (2.26)	108 (5.52)	2036 (2.34)	53.05
≥ 4 CC	572 (1.50)	48 (3.52)	620 (1.57)	77.42	258 (0.55)	11 (1.85)	269 (0.56)	40.89	830 (0.97)	59 (3.01)	889 (1.02)	66.37
p-value	p<0.0001											
Age (years) means (SD)												
	32.04 (8.58)	37.75 (12.14)	32.24 (16.81)		29.01 (7.48)	32.81 (9.23)	29.06 (7.51)		30.37 (8.13)	36.25 (11.56)	30.51 (8.27)	
Age groups (years)												
≤ 39 years	30661 (80.44)	810 (59.47)	31471 (79.71)	25.74	42113 (89.50)	450 (75.5)	42563 (89.32)	10.57	72774 (85.44)	1260 (85.44)	74034 (64.35)	17.02
40-59 years	7268 (19.04)	468 (34.36)	7736 (19.6)	60.5	4902 (10.42)	142 (23.823)	5044 (10.59)	28.15	12170 (14.29)	610 (14.29)	12780 (31.15)	47.73

≥ 60 years	189 (0.50)	84 (6.17)	273 (0.69)	307.7	41 (0.08)	4 (0.67)	45 (0.09)	88.89	230 (0.27)	88 (0.27)	318 (4.49)	276.73
p-value				p<0.0001				p<0.0001				p<0.0001
Marital status												
Single	17422 (47.05)	519 (39.77)	17941 (46.8)	28.93	27231 (59.61)	308 (53.94)	27539 (59.54)	11.18	44653 (53.99)	827 (44.08)	45480 (53.77)	18.18
Living with partner	1933 (5.22)	56 (4.29)	1989 (5.19)	28.15	2338 (5.12)	28 (4.9)	2366 (5.12)	11.83	4271 (5.16)	84 (4.48)	4355 (5.15)	19.29
Married	17673 (47.73)	730 (55.94)	18403 (48.01)	39.67	16112 (35.27)	235 (41.16)	16347 (35.34)	14.38	33785 (40.85)	965 (51.44)	34750 (41.08)	27.77
p-value				p<0.0001				p=0.0130				p<0.0001
Geographic Regions												
Bangkok	5522 (14.62)	193 (14.31)	5715 (14.61)	33.77	9028 (19.32)	120 (20.27)	9148 (19.41)	13.12	14550 (17.22)	313 (16.13)	14863 (17.19)	21.06
Central	8582 (22.72)	285 (21.13)	8867 (22.66)	32.14	12145 (25.99)	154 (26.01)	12299 (26.09)	12.52	20727 (24.53)	439 (22.62)	21166 (24.49)	20.74
North	7391 (19.57)	268 (19.87)	7659 (19.58)	34.99	7987 (17.09)	108 (18.24)	8095 (17.17)	13.34	15378 (18.20)	376 (19.37)	15754 (18.22)	23.87
Northeast	9207 (24.37)	347 (25.72)	9554 (24.42)	36.32	8382 (17.94)	102 (17.23)	8484 (18.00)	12.02	17589 (20.82)	449 (23.13)	18038 (20.87)	24.89
East	2312 (6.12)	85 (6.30)	2397 (6.13)	35.46	2898 (6.20)	32 (5.41)	2,930 (6.22)	10.92	5,210 (6.17)	117 (6.03)	5,327 (6.16)	21.96
South	4,762 (12.61)	171 (12.68)	4,933 (12.61)	34.66	6,285 (13.45)	76 (12.84)	6,361 (13.49)	11.95	11,047 (13.07)	247 (12.73)	11,294 (13.07)	21.87
p-value				p=0.7540				p=0.8950				p=0.0580
Life course residence**												
Rural-rural (RR)	17,012 (45.27)	595 (45.04)	17607 (45.26)	33.79	19,899 (42.75)	238 (40.55)	20137 (42.72)	11.82	36,911 (43.88)	833 (43.69)	37744 (43.87)	22.07
Rural-urban (RU)	12,227 (32.53)	392 (29.67)	12619 (32.44)	31.06	14,657 (31.49)	157 (26.75)	14814 (31.43)	10.6	26,884 (31.95)	549 (28.77)	27433 (31.89)	20.01
Urban-rural (UR)	1,621 (4.31)	78 (5.90)	1699 (4.37)	45.91	1,981 (4.26)	27 (4.60)	2008 (4.26)	13.45	3,602 (4.28)	105 (5.50)	3707 (4.31)	28.32
Urban-urban (UU)	6,722 (17.89)	256 (19.38)	6978 (17.94)	36.67	10,008 (21.50)	165 (28.11)	10173 (21.58)	16.22	16,730 (19.89)	421 (22.06)	17151 (19.93)	24.55
p-value				p=0.0010				p=0.0070				p=0.001
Education level												
Junior school	1845 (4.85)	126 (9.29)	1971 (5.00)	63.93	1049 (2.24)	19 (3.19)	1068 (2.25)	17.79	2894 (3.41)	145 (7.43)	3039 (3.50)	47.71
High school	19115 (50.27)	664 (48.93)	19779 (50.22)	33.57	19365 (41.27)	270 (45.38)	19635 (41.32)	13.75	38480 (45.3)	934 (47.85)	39414 (45.35)	23.7
Diploma	8609 (22.64)	294 (21.67)	8903 (22.61)	33.02	14384 (30.65)	181 (30.42)	14565 (30.655)	12.43	22993 (27.07)	475 (24.34)	23468 (27.00)	20.24
University	8459 (22.24)	273 (20.12)	8732 (22.17)	31.26	12128 (25.84)	125 (21.01)	12253 (25.78)	10.2	20587 (24.22)	398 (20.39)	20985 (24.15)	18.97
p-value				p<0.0001				p=0.0170				p<0.0001
Personal monthly income (baht)												
≤ 7000 baht	13166 (35.39)	443 (34.05)	13609 (35.35)	32.55	21775 (47.47)	251 (43.2)	22026 (47.41)	11.40	34941 (42.06)	694 (36.88)	35635 (41.94)	19.48
7001-10000 baht	8539 (22.95)	282 (21.68)	8821 (22.91)	31.97	10860 (23.67)	117 (20.14)	10977 (23.63)	10.66	19399 (23.35)	399 (21.20)	19798 (23.30)	20.15

10001-20000 baht	10561 (28.39)	360 (27.67)	10921 (28.36)	32.96	9503 (20.72)	145 (24.96)	9648 (20.77)	15.03	20064 (24.15)	505 (26.83)	20569 (24.21)	24.55
≥ 20001 baht	4936 (13.27)	216 (16.60)	5152 (13.38)	41.93	3735 (8.14)	68 (11.70)	3803 (8.19)	17.88	8671 (10.44)	284 (15.09)	8955 (10.54)	31.71
p-value				p=0.0010				p<0.0001				p<0.0001

CMR per 1000*: 15-year cumulative mortality probability per 1000.
 Life course residence**: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) (16, 19, 21, 22).

Supplementary Table 2: Univariate hazard ratios (HRs) according to multimorbidity, number of chronic conditions (CC) and risk factors (Thailand, 2005 for baseline characteristics and 2019 for all-cause mortality).

Participants								
	Male			Female			Total	
	HR	(95 % CI)		HR	(95 % CI)		HR	(95 % CI)
Two or more chronic conditions								
Multimorbidity								
No	1.00			1.00			1.00	
Yes	1.83	(1.62, 2.06)		2.37	(1.92, 2.93)		2.29	(2.06, 2.54)
Number of chronic conditions (CC)								
0 CC	1.00			1.00			1.00	
1 CC	1.41	(1.24, 1.59)		1.72	(1.43, 2.06)		1.64	(1.48, 1.82)
2 CC	1.87	(1.60, 2.19)		2.55	(1.97, 3.30)		2.41	(2.11, 2.76)
3 CC	2.40	(1.92, 3.01)		3.49	(2.26, 5.38)		3.29	(2.70, 4.02)
≥ 4 CC	2.97	(2.21, 3.98)		4.38	(2.40, 8.00)		4.15	(3.19, 5.40)
p-trend	0.0001			0.0001			0.0001	
Socio-demographic factors								
Gender	1.00			0.36	(0.33, 0.40)			
Age (years)								
≤ 39 years	1.00			1.00			1.00	
40-59 years	2.39	(2.13, 2.67)		2.68	(2.22, 3.24)		2.84	(2.58, 3.13)
≥ 60 years	13.79	(11.02, 17.27)		8.61	(3.22, 23.05)		18.47	(14.88, 22.93)
p-trend	0.1972			0.1220			0.2520	
Marital status								
Single	1.00			1.00			1.00	
Living with partner	0.97	(0.74, 1.28)		1.06	(0.72, 1.56)		1.06	(0.85, 1.33)
Married	1.38	(1.23, 1.54)		1.29	(1.09, 1.52)		1.53	(1.40, 1.68)
Geographic regions								
Bangkok	1.00			1.00			1.00	
Central	0.95	(0.79, 1.14)		0.95	(0.75, 1.21)		0.98	(0.85, 1.14)
North	1.04	(0.86, 1.25)		1.02	(0.78, 1.32)		1.13	(0.98, 1.32)
Northeast	1.08	(0.90, 1.28)		0.92	(0.70, 1.19)		1.18	(1.02, 1.37)

East	1.05	(0.81, 1.36)	0.83	(0.56, 1.23)	1.04	(0.84, 1.29)
South	1.03	(0.84, 1.26)	0.91	(0.68, 1.21)	1.04	(0.88, 1.23)
Life course residence*						
Rural-rural (RR)	1.00		1.00		1.00	
Rural-urban (RU)	0.92	(0.81, 1.04)	0.90	(0.73, 1.10)	0.91	(0.81, 1.01)
Urban-rural (UR)	1.37	(1.08, 1.73)	1.14	(0.76, 1.70)	1.29	(1.05, 1.58)
Urban-urban (UU)	1.08	(0.94, 1.26)	1.38	(1.13, 1.68)	1.11	(0.99, 1.25)
Education level						
Junior school	1.00		1.00		1.00	
High school	0.52	(0.43, 0.63)	0.77	(0.49, 1.23)	0.49	(0.41, 0.58)
Diploma	0.51	(0.41, 0.63)	0.70	(0.44, 1.12)	0.42	(0.35, 0.50)
University	0.48	(0.39, 0.59)	0.57	(0.35, 0.93)	0.39	(0.32, 0.47)
p-trend	0.1891		0.0243		0.1436	
Personal monthly income (baht)						
≤ 7000 baht	1.00		1.00		1.00	
7001-10000 baht	0.98	(0.84, 1.14)	0.93	(0.75, 1.16)	1.03	(0.91, 1.17)
10001-20000 baht	1.01	(0.88, 1.16)	1.32	(1.08, 1.62)	1.26	(1.13, 1.42)
≥ 20001 baht	1.29	(1.10, 1.52)	1.57	(1.20, 2.05)	1.64	(1.42, 1.88)
p-trend	0.0380		0.0650		0.0077	
Health behaviours/ Personal lifestyles						
Diet consumptions						
Deep fried food						
Never	1.00		1.00		1.00	
1-3 times/month	0.66	(0.49, 0.89)	0.63	(0.41, 0.98)	0.63	(0.50, 0.81)
1-2 times/week	0.54	(0.41, 0.71)	0.66	(0.43, 1.00)	0.58	(0.46, 0.73)
3-6 times/week	0.53	(0.40, 0.70)	0.54	(0.35, 0.82)	0.56	(0.44, 0.70)
Daily or more	0.52	(0.39, 0.70)	0.50	(0.32, 0.78)	0.53	(0.41, 0.68)
p-trend	0.0716		0.0531		0.0854	
Instant food						
Never	1.00		1.00		1.00	
1-3 times/month	0.68	(0.59, 0.78)	0.74	(0.60, 0.92)	0.67	(0.59, 0.75)
1-2 times/week	0.67	(0.58, 0.78)	0.69	(0.54, 0.87)	0.66	(0.58, 0.75)
3-6 times/week	0.70	(0.58, 0.83)	0.74	(0.56, 0.98)	0.70	(0.60, 0.81)

Daily or more	0.57	(0.39, 0.83)	0.65	(0.38, 1.11)	0.56	(0.41, 0.77)
p-trend	0.0910		0.0967		0.0975	
Soft drink						
Never	1.00		1.00		1.00	
1-3 times/month	0.81	(0.70, 0.94)	0.78	(0.63, 0.97)	0.88	(0.77, 0.99)
1-2 times/week	0.73	(0.63, 0.85)	0.76	(0.60, 0.96)	0.86	(0.76, 0.98)
3-6 times/week	0.73	(0.62, 0.87)	0.97	(0.76, 1.24)	0.95	(0.83, 1.09)
Daily or more	0.72	(0.57, 0.91)	0.97	(0.71, 1.32)	0.88	(0.73, 1.06)
p-trend	0.0679		0.7935		0.4406	
Soybean products						
Never	1.00		1.00		1.00	
1-3 times/month	0.83	(0.71, 0.98)	0.80	(0.59, 1.08)	0.80	(0.69, 0.92)
1-2 times/week	0.89	(0.76, 1.05)	1.02	(0.77, 1.35)	0.85	(0.74, 0.98)
3-6 times/week	0.94	(0.80, 1.12)	1.06	(0.80, 1.40)	0.85	(0.73, 0.98)
Daily or more	1.03	(0.83, 1.29)	1.07	(0.79, 1.46)	0.81	(0.68, 0.96)
p-trend	0.5643		0.3128		0.2364	
Vegetable (serves/day)						
0-4	1.00		1.00		1.00	
5-9	1.07	(0.84, 1.37)	0.68	(0.43, 1.08)	0.96	(0.77, 1.19)
10-14	0.82	(0.51, 1.33)	1.23	(0.66, 2.29)	0.97	(0.66, 1.42)
≥ 15	1.80	(1.02, 3.18)	0.36	(0.05, 2.57)	1.41	(0.82, 2.43)
p-trend	0.2120		0.4047		0.1327	
Fruit (serves/day)						
0-4	1.00		1.00		1.00	
5-9	0.95	(0.80, 1.13)	0.90	(0.71, 1.14)	0.86	(0.75, 0.99)
10-14	1.04	(0.80, 1.35)	0.77	(0.51, 1.16)	0.89	(0.71, 1.11)
≥ 15	1.42	(0.93, 2.17)	0.67	(0.30, 1.51)	1.07	(0.74, 1.56)
p-trend	0.0841		0.0406		0.4517	
Activity status						
Weekly exercise (sessions)#						
0-7	1.00		1.00		1.00	
8-14	0.89	(0.78, 1.01)	0.99	(0.82, 1.20)	1.08	(0.97, 1.20)
≥ 15	0.95	(0.84, 1.08)	1.16	(0.92, 1.45)	1.32	(1.18, 1.47)
p-trend	0.7514		0.2735		0.0877	

Housework							
Never	1.00		1.00		1.00		
1-3 times/month	0.89	(0.71, 1.12)	0.84	(0.54, 1.30)	0.85	(0.69, 1.04)	
Once or twice/week	0.81	(0.66, 1.00)	0.69	(0.47, 1.01)	0.67	(0.56, 0.81)	
3-4 times/week	0.81	(0.64, 1.02)	0.64	(0.41, 0.98)	0.67	(0.54, 0.82)	
Every day or more	1.20	(0.99, 1.46)	0.70	(0.49, 1.02)	0.79	(0.67, 0.94)	
p-trend	0.6186		0.0665		0.2002		
Sleeping time (hours)							
≤ 6 hours	1.20	(1.07, 1.35)	1.00	(0.83, 1.20)	1.17	(1.06, 1.29)	
7-8 hours	1.00		1.00		1.00		
≥ 9 hours	1.25	(1.06, 1.47)	1.17	(0.93, 1.47)	1.19	(1.04, 1.36)	
p-trend	0.8852		0.3176		0.9389		
Sedentary time (hours)							
≤ 7 hours	1.00		1.00		1.00		
8-12 hours	0.88	(0.78, 0.99)	1.19	(0.99, 1.45)	0.90	(0.81, 1.00)	
≥ 13 hours	0.84	(0.73, 0.97)	1.11	(0.90, 1.36)	0.80	(0.72, 0.90)	
p-trend	0.1960		0.6231		0.0051		
Smoking and Drinking status							
Smoking							
Never smoking	1.00		1.00		1.00		
Smoking	1.79	(1.59, 2.00)	1.50	1.11, 2.01)	2.58	(2.36, 2.82)	
Drinking							
Never	1.00		1.00		1.00		
Ex-drinker	1.12	(0.94, 1.35)	1.16	(0.97, 1.37)	0.81	(0.72, 0.91)	
Occasional or social	1.62	(1.37, 1.90)	2.31	(1.14, 4.67)	2.22	(1.90, 2.59)	
Current regular	2.03	(1.76, 2.34)	1.61	(1.22, 2.13)	2.02	(1.78, 2.29)	
p-trend	0.0232		0.3420		0.3420		

p-trend **bolding**: The results of p-trend were statistical significance.

Life course residence*: Life course residence was categorized in terms of rural (R) or urban (U) residential residence, when aged 10–12 years old and again in 2005, creating four groups: lifelong ruralites (Rural-rural, RR), urbanizers (Rural-urban, RU), de-urbanizers (Urban-rural, UR) and urbanites (Urban-urban, UU) (16, 19, 21, 22).

Weekly exercise#: The Combined measure of weekly physical activities: “2 × vigorous exercises + 1 × moderate exercises + 1 × walking sessions per week”, which was on the basis of International Physical Activity Questionnaire and the Active Australia Survey (21, 22).

Chapter 10 The prevention and management of multimorbidity in Southeast Asia

Building on the regional overview presented in Chapter 4, which systematically reviewed multimorbidity prevalence and the association with educational attainment across Southeast Asia, the subsequent chapters (5 to 9) focused on Thailand as the detailed study. These chapters analysed the risk factors, geographic disparities, latent classes of diseases, and mortality outcomes using nationally representative data from the Thai Cohort Study. Thailand was selected not only for the availability of comprehensive longitudinal data but also because it is a large middle-income country undergoing rapid demographic and epidemiological transitions, making its findings broadly informative for the Southeast Asian region.

This chapter aims to extend the discussion to the broader Southeast Asian context by examining current multimorbidity prevention and management strategies. It reviews preventive measures, including initiatives to improve health literacy and health promotion, address social determinants of health, and foster stakeholder engagement. It also examines strategies for managing multimorbidity, such as strengthening primary healthcare systems, optimizing medication regimens to prevent polypharmacy, and integrating digital health solutions. By synthesizing regional evidence and drawing on insights from the Thai case study, this chapter provides evidence-based recommendations to guide future efforts in multimorbidity prevention and management across Southeast Asia.

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I declare that the research presented in this Thesis represents original work that I carried out during my candidature at the Australian National University, except for contributions to multi-author papers incorporated in the Thesis where my contributions are specified in this Statement of Contribution.

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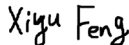
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Prevention and Management of Multimorbidity in Southeast Asia: A Narrative Review

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Correspondence: Xiyu Feng (xiyu.feng@anu.edu.au)**Received:** 28 March 2024 | **Revised:** 20 June 2024 | **Accepted:** 26 June 2024**Funding:** The authors received no specific funding for this work.**Keywords:** controlling | intervention | management | multimorbidity | multiple chronic conditions | non-communicable diseases | prevention

ABSTRACT

Multimorbidity, the coexistence of two or more chronic conditions, presents a growing global challenge, particularly in low- and middle-income countries such as Southeast Asia. This trend necessitates the development of sustainable integrated care models to prevent and manage multimorbidity effectively. However, progress in this area has been hampered, especially in underdeveloped regions, by various barriers, including the epidemiology of multimorbidity, how to get different specialists and doctors to work together most available and manage the multiple medication issues and how to develop cost-effective approaches to reduce the health burden of multimorbidity. Preventive measures in Southeast Asia, which could tackle multiple components which commonly comprise multimorbidity, include enhancing health literacy and health promotion through school- and community-based educational activities, primary healthcare and related policies on employing taxes on tobacco, alcohol and sugary beverages. The social determinants of health-encompassing poverty and low education may also influence research on multimorbidity. Moreover, stakeholder engagements involving national governments, World Health Organization (WHO) and Association of Southeast Asian Nations (ASEAN) are crucial. Management strategies focus on integrated care models, including patient-centred primary healthcare, digital healthcare technologies, and medication management to control polypharmacy. Although research on multimorbidity in Southeast Asia is increasing, translating findings into practical measures was limited. Future efforts should prioritize evidence-based approaches to prevent and manage multimorbidity effectively, addressing challenges like health system focusing on single chronic disease treatment independently, resource limitations, healthcare provider shortages and individual adherence issues. These ways promise to enhance the quality of life and health outcomes in this region.

1 | Introduction

Multimorbidity is a condition in which a person suffers from two or more chronic diseases at the same time [1–3]. One of the most important drivers of multimorbidity prevalence is population ageing, and older people are more susceptible to multimorbidity [1, 4, 5]. Multimorbidity has become an increasingly recognized global problem, as it complicates treatment regimens,

increases healthcare utilization and poses significant burdens on individuals and healthcare systems [1, 4].

Research on effective prevention and management approaches for multimorbidity is lacking, especially in low- and middle-income countries (LMICs), where the focus has primarily been on individual non-communicable diseases (NCDs) [1, 5]. LMICs generally have younger populations and lower multimorbidity

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prevalence. However, rapid demographic shifts in recent decades, particularly in Southeast Asia, have led to population ageing and a transition from infectious to chronic diseases as major health burdens [1, 6, 7]. Additionally, LMICs often face challenges such as poorly resourced healthcare systems, outdated medical technologies and uneven access to healthcare services, which can delay diagnosis and contribute to the development of multimorbidity [1, 4, 5].

The prevention and management of multimorbidity is not simply a matter of considering NCDs but also including attention to chronic infectious diseases such as tuberculosis (TB) and HIV, and psychiatric disorders, including bipolar disorder and depression [1, 4, 6]. A particular challenge of multimorbidity is the associated use of multiple medications (polypharmacy) and increased risk of drug interactions. This is especially challenging for primary healthcare in low-resource settings, which may be the first point of contact between the healthcare system and the patient. Multimorbidity may require a higher level of healthcare demand [1, 2] in LMICs settings where primary healthcare systems may not be adequately resourced [1–3].

Preventing and managing multimorbidity present a complex challenge that demands a comprehensive approach [1–4], considering various risk factors, including individual, social and environmental determinants. However, prevention and management approaches for multimorbidity remain limited, with most strategies focusing on individual chronic conditions [1, 5, 6]. Managing multimorbidity requires an integrated approach that acknowledges the intricate interactions between multiple health conditions, treatments and patient preferences [4, 5]. It is crucial to optimize disease control while minimizing treatment burden and the potential harms of polypharmacy [5, 6]. Emphasizing patient-centred care, shared decision-making and coordinated care across healthcare settings are essential for successful prevention and management of multimorbidity [1, 6].

In Southeast Asia, the rising prevalence of multimorbidity is driven by factors like population ageing, changing disease patterns and lifestyle shifts due to rapid urbanization and industrialization [1, 7, 8]. Unhealthy diets, physical inactivity and substance abuse are key contributors to multimorbidity risk [8, 9]. Additionally, the region is witnessing a significant increase in its elderly population, projected to reach 24.1% by 2050 from 8.8% in 2018 [8]. This demographic shift has led to a transition in health challenges, with a decline in communicable diseases like malaria and an increase in chronic NCDs such as cardiovascular diseases (CVD), diabetes and chronic respiratory diseases. Multimorbidity prevalence has risen from around 4.5% to approximately 10% in recent years, with hypertension, CVD and diabetes mellitus being the most prevalent chronic diseases [7, 9, 10]. Despite efforts such as universal health insurance schemes to tackle chronic diseases, integrated care for multimorbidity remains a challenge in Southeast Asian healthcare systems [7, 9, 10].

This article provides a comprehensive overview of the current status of multimorbidity prevention and management strategies in Southeast Asia. Through the exploration of prevention initiatives, covering health literacy promotion, addressing social determinants of health and stakeholder engagement, as well as methods for managing multimorbidity focusing on integrated

care models, including strengthening primary healthcare, optimizing medication management and utilizing digital health tools, to offer insights and recommendations for guiding future efforts in multimorbidity prevention and management in the region.

2 | Search Strategy

Articles were selected on the basis of inclusion criteria focused on the prevention and management of multimorbidity and/or NCDs in Southeast Asia. These criteria included studies conducted in Southeast Asian countries or the region defined by the Association of Southeast Asian Nations (ASEAN), with publication dates between 1990 and 5 April 2024, given the term ‘multimorbidity’ originated in the early 1990s [1]. Exclusion criteria encompassed conference papers, studies outside Southeast Asia and those not published in English within the specified timeframe.

Database searches on Google Scholar, PubMed and Scopus were conducted using terms related to exposure (prevention, management, or their related synonyms), outcomes (multimorbidity or its related synonyms) and location (Southeast Asia or specific countries). The searches were divided into prevention and management categories, with terms combined using ‘AND’ across categories and ‘OR’ within categories. Hand searches of retrieved study references were also performed to find additional relevant papers.

3 | Prevention of Multimorbidity

Many of the chronic diseases which comprise multimorbidity share common behavioural risk factors, including alcohol consumption and smoking, sedentariness and diets high in fat, sugar and sodium, socio-economic risk factors, including low education and income, and health inequalities (inability to obtain adequate medical treatment and to afford the corresponding medical expenses) [1, 10]. Common approaches to preventing multimorbidity include improving health literacy and health promotion, addressing social determinants of health and the stakeholder engagement. The summary of key factors for the prevention and management of multimorbidity in Southeast Asia is shown in Figure 1.

3.1 | Improvement of Health Literacy and Health Promotion

Health literacy efforts can raise awareness of risk factors associated with multimorbidity and the importance of adopting a healthy lifestyle. Promoting knowledge about preventive measures such as regular physical activity, healthy eating habits, smoking cessation and stress management can empower individuals to make informed choices and reduce the risk of developing multimorbidity [11]. For example, many countries, such as Singapore, Malaysia, Indonesia and Thailand in Southeast Asia, implement comprehensive health literacy programmes in schools that cover a wide range of topics, including nutrition, physical activity, mental health, sexual and reproductive health, and the prevention of chronic conditions [7, 9]. The curriculum aims to

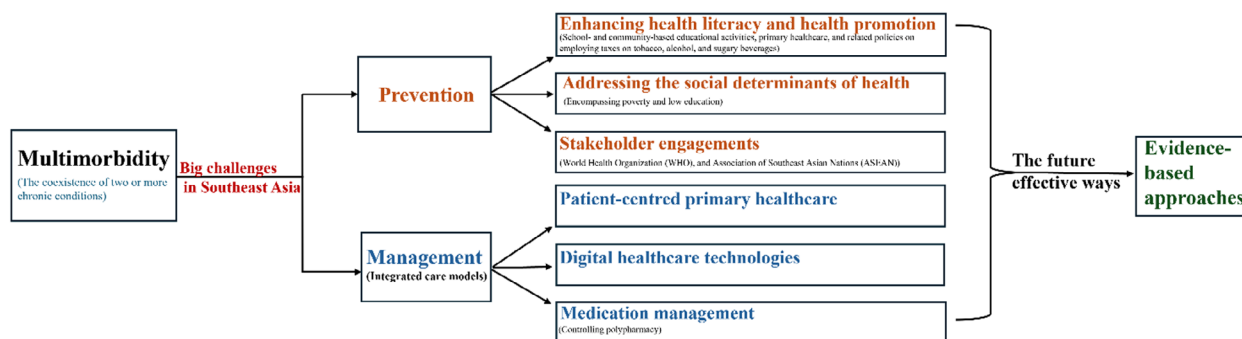


FIGURE 1 | Key factors for the prevention and management of multimorbidity in Southeast Asia.

equip students with the knowledge and skills to make healthy choices and prevent NCDs [7, 9]. Although there is less clear policy on health literacy specifically to prevent multimorbidity, addressing common risk factors for NCDs through health literacy in a study conducted in Singapore reduced the prevalence of multimorbidity [12].

In addition to schools, health literacy in the community is also very important. Thailand and Malaysia encourage community-based health education programmes facilitated by community health centres and community health volunteers [7, 9]. These programmes provide health education sessions, workshops and screenings to promote healthy behaviours and early detection of health issues [7, 9, 12].

As for the health promotion, lifestyles, including smoking and alcohol consumption, diets high in salt, sugar and oil, and sedentary behaviours, may cause or exacerbate multimorbidity. Vietnam, Myanmar and Thailand employ taxes on tobacco, alcohol and sugary beverages to curb consumption and manage health risks [7, 9, 13]. The Health Promotion Foundation of Thailand also advocates for community-based physical activity programmes [13, 14]. Indonesia has implemented the 'Gerakan Masyarakat Hidup Sehat' (Healthy Living Community Movement) which promotes healthy lifestyles and NCDs and multimorbidity prevention through education, community engagement and policy changes such as tobacco control [15, 16]. Singapore's Health Promotion Board spearheads integrated strategies to promote healthy behaviours and prevent multimorbidity [17].

These health promotion activities in Southeast Asia are usually carried out through the preventative function of primary healthcare system. Primary healthcare in Southeast Asia is often the first point of contact for individuals seeking medical care [18, 19]. Reminding and urging people to start regular health check-ups, screening programmes and risk assessments at a relatively young age can help to identify risk factors and potential health problems at an early stage so that multimorbidity can be prevented in a timely manner [18, 19]. Furthermore, primary healthcare providers can also be involved in health promotion and education activities to raise health literacy and awareness of healthy lifestyles and prevention of multimorbidity. These could include educating the population about the importance of a balanced diet, regular physical activity, smoking cessation and limiting alcohol intake [18, 19].

3.2 | Addressing Social Determinants of Health

One way in which social determinants of health impact the risk of NCDs and multimorbidity is through socio-economic status (SES). Lower SES limits access to quality healthcare and preventive services, leading to delayed or inadequate care and increased NCDs and multimorbidity risks [1, 18]. Limited economic resources often lead to unhealthy lifestyle behaviours such as poor nutrition, physical inactivity and tobacco use exacerbating these risks [18]. Housing conditions, air quality and neighbourhood safety, influenced by social determinants, directly affect health outcomes, especially for those with low SES [18]. Furthermore, high external stress levels among low SES individuals compromise their health further [18].

The social determinants of health drive health inequalities that contribute to the occurrence of multimorbidity. For instance, healthcare inequalities contribute to an increased prevalence of multimorbidity among low-income people, as these individuals lack access to timely prevention and treatment related to multimorbidity [4–6]. Southeast Asian governments are addressing these determinants through policies establishing social protection mechanisms and universal health coverage [7, 9]. These policies aim to provide affordable, quality healthcare services to all citizens, regardless of SES, through initiatives like Universal Coverage Schemes (UCS) [7, 9].

It is vital to bridge cultural and ethnic disparities, particularly in Southeast Asia, where diverse languages and cultures exist. Language barriers can lead to miscommunication, delaying diagnosis and treatment, worsening health outcomes and contributing to multimorbidity [1, 6, 7, 9]. Cultural norms affect dietary habits, activity levels and mental health perceptions, impacting multimorbidity risk factors. Healthcare access disparities based on culture and SES worsen disease burdens in marginalized communities, increasing multimorbidity risks [1, 6, 7, 9].

Government initiatives such as Singapore's Community Health Assistance Scheme (CHAS) subsidize healthcare for low- and middle-income individuals and marginalized groups, enhancing access to quality care [9, 19]. Although some Southeast Asian countries have social assistance programmes such as Indonesia's Family Hope Program, aiming to support marginalized groups, their impact on multimorbidity remains unclear [20]. Effective addressing of health determinants, including prevention

of multiple diseases, relies heavily on government support and engagement [18, 21].

3.3 | Stakeholder Engagement

With the epidemiological transition in the Southeast Asian region, the importance of NCDs has been increasing and all government efforts are required to address this challenge given the complex causal pathways. Governments in Southeast Asia have established inter-ministerial committees or working groups involving health, social welfare, education and other related sectors to comprehensively address NCDs [7, 9]. For example, in Thailand, the Ministry of Interior and the Ministry of Health issued a joint statement on the prevention and control of NCDs [22]. Similar policies have been introduced in Indonesia [23] and Myanmar [24]. Although these measures aim to address some of the risk factors common across NCDs, little attention has been given specifically to multimorbidity.

The World Health Organization (WHO) and the ASEAN, the regional organization of 10 Southeast Asian and Pacific Rim countries, including Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam, whose governments cooperate to promote the socio-cultural, economic and political progress of the region [25], have carried out a range of efforts to prevent NCDs such as *Implementation roadmap for accelerating the prevention and control of NCDs in South-East Asia 2022–2030* [7] and *Framework for the Development and Implementation of Fiscal Measures on Sweet Beverages to Promote Health in ASEAN Member States* [25], but for multimorbidity prevention, these organizations do not have a dedicated programme.

This is also true for individual countries in the Southeast Asian region. In Indonesia, the government's project on chronic disease prevention in collaboration with community health centres (Puskesmas) does not address multimorbidity [26]. Moreover in Malaysia [27] and Singapore [28], the government's partnership with private healthcare providers and non-governmental organizations (NGOs) to implement preventive healthcare programmes, including screening, health education as well as lifestyle interventions, only mentioned NCDs individually.

4 | Management of Multimorbidity

Integrated care models play an important role in addressing the complex healthcare needs of individuals with multimorbidity. These models ensure that patients receive comprehensive and holistic treatment tailored to their specific combination of chronic conditions [29, 30]. The multimorbidity management could be optimized by integrated care models, emphasizing continuity of care, personalized interventions and efficient resource utilization. Consequently, they significantly contribute to improving patient outcomes and reducing healthcare costs associated with managing multimorbidity [29–31].

4.1 | Enhancing Primary Healthcare

The crucial role primary healthcare plays in improving health literacy and prevention of multimorbidity, and this sector also plays a key role in the management of the conditions which make up multimorbidity [21]. Primary healthcare providers are trained to provide a person-centred and making-sharing continuum of care that addresses not only the physical health of the individual, but also their psychosocial and preventive needs [21, 29, 30].

Primary healthcare services are generally more accessible and affordable compared to specialized care. By managing multimorbidity at the primary healthcare level, individuals can receive timely and cost-effective care [29, 30]. They are often not only the point of first screening and diagnosis for NCDs but also the treatment point. Although diagnosis, screening or acute care may occur in hospital settings, the primary healthcare sector is responsible for guidance on maintaining healthy lifestyles medication adherence, and general advice [29, 30]. Although the management of multimorbidity in Southeast Asia is still limited at this stage, with most of the management focusing on individual NCDs, they are also useful and instructive for multimorbidity [21, 29, 30].

The management of multimorbidity, like for individual NCDs, requires the development of well-coordinated care models across different healthcare organizations and settings. Examples of such models can be found in Southeast Asian countries such as Thailand [31, 32] and Singapore [33, 34], where UCS programmes have been implemented. These programmes ensure the payment of medical expenses for the insured and promote the universalization and development of basic healthcare services [31, 32]. Through reasonable health insurance policies, medical institutions are encouraged to provide essential medical services and receive appropriate remuneration, making healthcare more accessible [31, 32]. As a result, people have better access to a range of healthcare services, from primary care to specialty and hospital services. Additionally, UCS can provide long-term medical support to patients with chronic diseases and multimorbidity. For instance, in particular setting, it can incorporate routine blood pressure and blood glucose monitoring into medical consultations for hypertensive and diabetic patients, thus easing their financial burden [31, 32].

The management of multimorbidity in primary healthcare presents complexities beyond those of individual NCDs. An integrated care model incorporating patient-centred care and decision-sharing is recommended [35, 36]. The patient-centred model prioritizes the patient's individual needs, culture and religious beliefs, treatment goals, values and preferences, recognizing their central role in healthcare decision-making. Healthcare providers engage in open and honest communication, providing necessary information about conditions, treatment options, benefits and risks, involving patients in care planning and decision-making [35, 36].

Multimorbid patients often encounter complex medical situations, including the simultaneous presence of multiple diseases, treatment regimen interactions and treatment choice uncertainty [37, 38]. For example, a patient dealing with both diabetes

and hypertension may have unique treatment preferences and values, such as favouring non-pharmacological interventions and cultural and religious taboos. A patient-centred approach entails discussing these options openly, providing information on benefits and risks, and collaboratively developing a treatment plan aligned with the patient's preferences and values [37, 38]. This collaborative approach improves treatment adherence, satisfaction and overall effectiveness in managing multiple conditions [36, 38].

There are also many randomized controlled trials (RCT) on primary healthcare systems in the management of multimorbidity, especially in Europe and North America, and fewer studies in Southeast Asia [39, 40]. The management used in these RCTs includes self-management, medication optimization and treatment refinement and generally involves intervention levels of patient-level, provider-level, organizational-level and integrated level (combining two or three of the above levels). In terms of results, the integrated level has been found to be the most effective, although the results of the trials have been more mixed [39, 40]. Therefore, it can also be argued that integrated interventions are an important part of the future management of multimorbidity in primary care.

Thailand has prioritized primary healthcare in national reform efforts, employing a 'task-shifting' strategy to train health workers for primary care [32]. Programmes, such as District Health Management Learning (DHML) and Contracting Unit of Primary Care (CUPC), focus on patient-centred services for those with multimorbidity [41]. Similarly, Singapore has expanded community-based primary care initiatives, like the National University Health System-Regional Health System Integrated Interventions and Care Extension (NUHS-RHS NICE programme), aiming to enhance post-hospital discharge care for multimorbid patients [42]. Furthermore, in Indonesia, an integrated primary healthcare using a life course approach for managing multimorbidity is underway in this region, considering a variety of health determinants and socio-economic factors such as consumption patterns, environment and physical activity [43].

Such integrated primary healthcare is based on the development of an individualized care plan that addresses disease management, medication management, lifestyle modifications and preventive measures based on the multimorbid patient's specific needs, goals and preferences and considers the patient's priorities, which are reviewed and adjusted on a regular basis in accordance with the patient's changing needs and preferences [1, 44]. This is undoubtedly a very effective way of managing multimorbidity, which is variable, and the only way to do so is through integrated, personalized and professional care [1, 44].

4.2 | Polypharmacy and Medication Management

Medication management is also a significant aspect of control for multimorbidity. Concerns have been raised about the polypharmacy needs required to manage multiple conditions and the potential for interactions among different drugs. Drug combinations may increase adverse effects, and some medications reduce the efficacy of other medications [45, 46]. For example, antipsy-

chotics may trigger diabetes and hyperlipidaemia and such drug may intervene the efficacy of hypoglycaemic drugs [45, 46].

Most Southeast Asian countries, such as Thailand, Myanmar and the Philippines, have the National List of Essential Medicines (NLEM), for treating common health problems that are safe and effective treatments [47, 48]. NLEM in these countries would offer healthcare providers with references and guidelines to determine appropriate medication use for various health conditions. It could help promote rational medication use by identifying essential medications that are safe, effective and cost-efficient.

For patients with multimorbidity, the current NLEM in Southeast Asian countries may not fully meet their needs, as it primarily focuses on medications for single diseases. This can lead to challenges related to polypharmacy, where patients require multiple medications, increasing risk of drug-drug interactions, adverse drug events and drug-related injuries [45–48]. Thus, against this backdrop, efforts to reduce polypharmacy through trials, including those in Singapore [47], have become more common. The aim is to ensure patients receive a safe, rational and effective range of medications [49, 50].

4.3 | Digital Health

In Southeast Asia, digital health is gaining importance particularly for remote communities [13]. Digital health technologies like telemedicine, mHealth and eHealth applications help to overcome the barriers to accessing healthcare services in Southeast Asia, especially in the primary healthcare sector. Telemedicine is a very important component of digital health, enabling patients to receive medical advice, consultation and follow-up care without travelling or long waiting times [51]. In addition, digital health tools such as wearable devices, including real-time blood pressure monitoring, home monitoring systems and mHealth apps that upload daily health data, are gaining acceptance in some countries in Southeast Asia [51].

Digital health can enable more efficient communication and record monitoring between specialists treating patients of multimorbidity [51, 52]. Patients can upload vital signs and medication data that are publicly available to all healthcare staff involved in the treatment, allowing these health professionals to discuss changes in their conditions together in real time and to remotely monitor their health status and intervene when necessary [52]. Moreover, it is convenient for these patients to be aware of their health changes without having to visit the healthcare provider's office [52].

Electronic health records (EHRs) are a very critical part of digital health platforms [51, 52]. EHRs serve as centralized repositories for storing and accessing comprehensive patient information. In the context of multimorbidity, EHRs provide healthcare providers with a comprehensive view of the patient's medical history, including diagnoses, medications, allergies and test results. This comprehensive information helps healthcare professionals understand the complexities and interactions among different conditions, enabling more accurate diagnoses and appropriate treatment plans [52, 53].

Thailand has been actively promoting the adoption of EHRs and has developed the Health Information System (HIS) to facilitate data sharing and integration among healthcare providers. This system includes initiatives aimed at improving chronic disease management, including multimorbidity [32, 54]. Thailand has implemented legal frameworks and guidelines to safeguard patient data privacy and security within the EHR system [54, 55]. Similarly, Singapore has made significant progress in EHR uptake and integration, with the implementation of the National EHR (NEHR) system. This platform offers healthcare providers a secure and comprehensive means of accessing patient information across various healthcare settings, supporting care coordination, medication reconciliation and evidence-based decision-making for multimorbidity management. Singapore also enforces robust regulations and privacy laws to protect patient data in electronic medical records [54, 56, 57]. Countries like Vietnam, Myanmar and Indonesia are also actively working on developing and delivering their own EHR systems [51].

5 | Challenges of Prevention and Management of Multimorbidity

Limited healthcare resources in Southeast Asia, including infrastructure, personnel and funding, pose challenges for preventive services such as screenings and early detection [7, 9]. For instance, inadequate medical facilities and equipment hinder necessary screenings and early detection, particularly in remote areas with uneven healthcare distribution. Shortages of doctors and nurses lead to delayed or inadequate diagnostic and treatment services, impacting early intervention opportunities. Insufficient funding may result in healthcare workers lacking essential skills and knowledge, affecting service quality [7, 9, 22]. Overall, resource scarcity impedes the implementation of prevention and management strategies for multimorbidity [1, 19]. Fragmented healthcare systems exacerbate the issue, causing communication gaps and coordination issues among providers, potentially leading to treatment conflicts and errors.

Although digital health is gaining popularity in Southeast Asia, health information-sharing and interoperability via digital platforms still encounter numerous challenges. Inconsistent standards, varying levels of digital health usage, and limitations in health information exchange infrastructure can hinder the sharing of patient information among healthcare providers [51]. This lack of interoperability affects coordination, continuity of care and a comprehensive understanding of a patient's multimorbidity [13, 58]. Patients with multimorbidity often have more complex medical data, and healthcare professionals may struggle to access all relevant information and identify the most critical health issues. Additionally, these individuals have complex medical needs, which may not be fully captured by existing EHRs [59].

Cultural beliefs, socio-economic factors, and health-seeking behaviours play a significant role in influencing multimorbidity prevention and management [39, 60]. Traditional practices, social norms and cultural beliefs can make an impact on the prevention and management of multimorbidity [1, 9, 60]. Southeast Asia is a diverse region with various ethnic groups, each with unique living habits, cultural practices and socio-economic backgrounds.

Understanding and addressing these cultural and socio-economic factors are crucial for developing effective prevention and management strategies tailored to the local context. However, this aspect of multimorbidity prevention and management is still underexplored in Southeast Asia [1, 7, 61].

6 | Recommendations

Although Southeast Asian countries have acknowledged the severity of multimorbidity and are actively addressing various issues related to it, there remains a pressing need to further implement and disseminate effective approaches for its prevention and management [9, 39]. It is essential that an evidence-based approach should be paramount in guiding future research endeavours and policy development concerning multimorbidity prevention and management. Greater emphasis on implementing evidence-based practices could improve the overall success in tackling the high burden of multimorbidity within the region [39, 61, 62].

As a first step, Southeast Asian countries may investigate the experiences of some high-income countries (HIC) countries in the introduction of prevention and management policies that specifically target multimorbidity, rather than just single chronic conditions [1, 7, 9, 61]. The Australian government for example has developed a manual on multimorbidity prevention and management in 2021. The manual not only describes in detail the prevalence of multimorbidity but also mentions the threat factors as well as some means of prevention and treatment, providing very valuable information for controlling multimorbidity [61].

Promoting healthy lifestyles is crucial for preventing and managing in multimorbidity, particularly among lower SES individuals in Southeast Asia [1, 63, 64]. Social support, community linkage and policy advocacy are essential for addressing health inequalities and improving living conditions [1, 40, 65]. Health education programmes empower individuals to make informed health decisions, which could improve the outcome of multimorbidity [65]. Apart from taxation policies, providing resources and facilities for maintaining a healthy lifestyle is vital for effective multimorbidity management [66]. Strategies like increasing fruit and vegetable intake [67] and regular exercise [68] are effective in controlling multimorbidity.

Other areas that need further refinements are primary healthcare as prioritizing NCDs over infectious diseases is still relatively new in many countries in Southeast Asia. Efforts towards integrated care models and patient-centred approaches require further refinement to effectively manage multimorbidity. Fragmentation and poor coordination within the primary healthcare system are common challenges, which can be addressed by promoting teamwork and communication among healthcare providers [7, 9].

Improving healthcare infrastructure, equipment and personnel is crucial, especially in remote areas of Southeast Asia. Constructing new medical facilities in these regions ensures access to basic services [1, 5]. Upgrading medical equipment enables advanced diagnostic and treatment capabilities. Providing multicultural training enhances staff skills to cater to diverse cultural

backgrounds [1, 7, 9, 22]. Engaging community residents in facility management enhances service sustainability [1, 6, 7, 9]. These measures aim to enhance healthcare accessibility and quality, for better addressing the prevention and management of multimorbidity in Southeast Asia.

Besides providing patients with optimal medication regimens within a patient-centred, shared decision-making, integrated care model to solve the polypharmacy issues, it is essential to raise awareness of drug interactions, individual symptom monitoring and strengthen comprehensive care for patients with multimorbidity training of the team, including disease-specific experts prescribing medications for multimorbid patients and involvement of pharmacists in reviewing medication lists to assess the risk of drug interactions [45–48]. At the same time, lifestyle management and social support to reduce medication side effects would also be necessary, especially in the context of easy access to prescription drugs [54, 68, 69]. In Southeast Asia, there are many drugs such as antibiotics and painkillers that are available without prescription, which may also lead to drug abuse, especially in the background of multimorbidity [47]. Culturally sensitive prevention and management strategies are crucial in a multi-ethnic region such as Southeast Asia to enhance the acceptability and effectiveness of interventions [1, 9, 60].

Although digital health in Southeast Asia is advancing, challenges persist with EHRs, especially in managing complex health needs of patients with multimorbidity. Current EHRs may struggle to capture timely changes in health status, and healthcare workers often face difficulty accessing comprehensive patient information due to varying standards [53, 54, 70]. To address these issues, enhancing EHR functionality, integrating them with other healthcare systems and standardizing practices are essential steps to cope with multimorbidity [52, 71].

7 | Conclusion

Addressing multimorbidity in Southeast Asia requires comprehensive prevention and management strategies. Prevention entails enhancing health literacy, involving stakeholders and addressing social determinants of health. Management involves adopting integrated care models, covering prioritize patient-centred primary healthcare, optimizing medication management and utilizing digital health technologies. Despite increasing research, translating findings into actionable interventions remains challenging. Future efforts should focus on evidence-based decision-making, strengthening healthcare infrastructure and developing relevant policies to overcome resource limitations and healthcare provider shortages. These endeavours aim to improve the quality of life and health outcomes for individuals in Southeast Asia.

Author Contributions

Xiyou Feng: conceptualization, writing – original draft, writing – review and editing, data curation. **Haribondhu Sarma:** writing – review and editing, supervision. **Matthew Kelly:** writing – review and editing, supervision.

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Ethics Statement

An ethical statement is not applicable because this study did not involve human or animal research as it is a review article.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

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Chapter 11 Discussion and Conclusion

11.1 Overview

The overarching goal of this thesis was to provide a comprehensive understanding of multimorbidity in Thailand, focusing on its prevalence, clustering patterns, risk factors, spatial distribution, mortality impact, and prevention strategies. To achieve this, the thesis includes one systematic review, one narrative review, three cross-sectional studies, and one mortality study. These studies collectively contribute to the existing literature by offering new insights into the burden and determinants of multimorbidity in Thailand, as well as identifying potential intervention areas.

Chapters 4 to 10 present the main findings related to these aspects. This chapter synthesizes and integrates those findings, comparing them with existing literature, guidelines, and reports to highlight their contributions to answering the research questions raised in Chapter 1.

Importantly, while this thesis primarily focuses on Thailand, the findings have broader relevance for Southeast Asia and other low- and middle-income countries (LMICs) experiencing similar demographic and epidemiological transitions. By examining multimorbidity using nationally representative cohort data, this research provides a framework for understanding the prevalence, patterns, and determinants of multimorbidity, which can inform evidence-based prevention and management strategies in comparable LMIC settings.

This chapter is organised around 5 main themes as follows:

Regional prevalence of multimorbidity and the role of education, this synthesis responds to research question 1 “How can regional prevalences of multimorbidity and their socio-economic drivers with a focus on education be understood?” (Chapter 4).

The findings reveal that there are large regional differences in the prevalence of multimorbidity across Southeast Asia, with educational attainment emerging as a key socioeconomic determinant. This study contributes to existing knowledge by synthesising the existing literatures through showing that education not only influences multimorbidity at the

individual level, but also in shaping regional health disparities. These insights can inform targeted public health policies to reduce health inequalities.

Common clusters of chronic conditions/multimorbidity patterns, synthesises the discussions of the findings regarding research question 2 “What are the common clusters of chronic conditions in the Thai Cohort Study (TCS)?” (Chapter 5 and Chapter 8).

The analysis identified distinct multimorbidity patterns. These findings advance the field of multimorbidity research by highlighting the clustering of these diseases, laying the foundation for more targeted prevention and management strategies in Thailand.

Risk factors for multimorbidity, this section responds to research question 3, “What are health-risk factors for multimorbidity in the TCS?” (Chapter 5, Chapter 6 and Chapter 8).

Results confirm well-established risk factors including older age and smoking, while also identifying new associations that are specific to the Thai population such as the importance of incidental exercise including housework. This study provides a more comprehensive assessment of how socio-demographic and behavioural determinants jointly influence the risk of multimorbidity.

Spatial distribution of multimorbidity addressed the research question 4 “What is the spatial distribution of multimorbidity prevalence in the TCS?” (Chapter 7 and Chapter 8).

The results show geographic clustering of high multimorbidity prevalence, highlighting the need for area-specific interventions in addition to individual-level prevention. This spatial perspective enhances current epidemiological understanding and supports geographically targeted health policies.

Mortality and multimorbidity. This section responds to research question 5, “Does multimorbidity increase mortality risk in the TCS?” (Chapter 9).

Results provide strong evidence that individuals with multimorbidity face a significantly higher risk of mortality than those without. By quantifying the excess mortality associated with multimorbidity, as well as identifying mitigating factors, this study highlights the urgency of multimorbidity interventions.

Prevention and management of multimorbidity answered the research question 6, “How can multimorbidity be prevented and managed in Southeast Asia?” (Chapter 10).

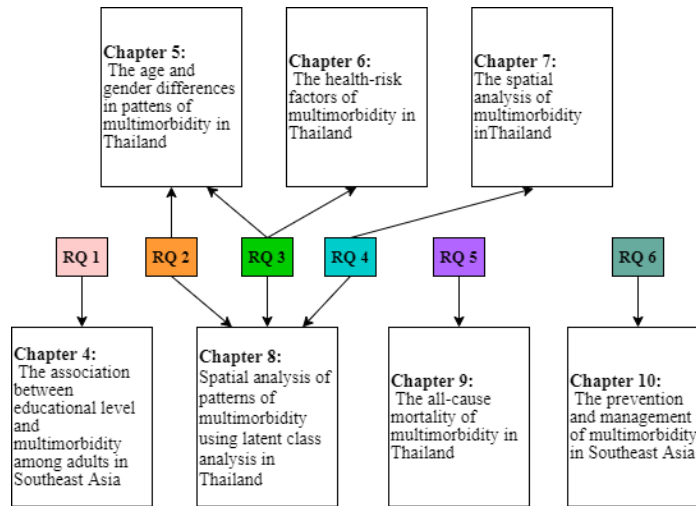
Based on the findings, this study highlights key prevention strategies, including education-driven health prevention and lifestyle interventions. In addition, it discusses the implications of healthcare system adjustments to better accommodate the growing burden of multimorbidity in the region.

Then, the discussion demonstrates the strengths and limitations of the thesis and discusses future research directions. Finally, the implications and contributions of this study to public health in Thailand are summarised.

Key findings summary

In the introduction of Chapter 1, six research questions were proposed to guide the research presented in this thesis. Key findings from these research questions are presented here, followed by a more detailed discussion of the findings, and their implications

- Relationships between educational attainment and multimorbidity show varying patterns across the Southeast Asia region, with the limited number and heterogeneity of the studies to date limiting the ability to draw conclusive answers and necessitating more research (Chapter 4).
- Based on data from the Thai Cohort Study, analysis of disease clustering within multimorbid people revealed metabolic syndromes to be the most prevalent grouping (Chapter 5). Latent class analysis further identified three patterns including metabolic syndromes, cardiometabolic disorders, and multi-system conditions (Chapter 8), varying by age and gender, highlighting the need for stratified studies.
- In Thailand, multimorbidity increased with age, was more common in men, and was linked to unhealthy diet and irregular sleep, while regular exercise, especially housework, reduced risk (Chapter 5, 6 and 8).
- Within Thailand, multimorbidity prevalence was higher in developed, high-income areas such as Bangkok, particularly for cardiometabolic disorders, suggesting a positive correlation with regional development (Chapter 7 and 8).
- Based on 14-year follow-up data from Thailand, individuals with multimorbidity had higher mortality risks, worsened by male sex, older age, lower SES, and unhealthy lifestyles, whereas higher education, income, and urbanization were linked to lower mortality risks (Chapter 9).
- The rising focus on multimorbidity in Southeast Asia's aging population calls for policy research, prevention efforts targeting health literacy and social determinants, and management strategies using integrated care models and digital health technologies (Chapter 10).



RQ: Research questions.

Figure 1 The summary of the key findings from the research and how the results chapters relate to the research questions.

11.2 Regional prevalence of multimorbidity and the role of education

The first research question was addressed using a systematic review (Chapter 4) of existing studies on the prevalence of multimorbidity in Southeast Asia including Thailand and the impact of educational level (one of main indicators of socio-economic status (SES)) on multimorbidity, in order to gain a general understanding of both the multimorbidity prevalence, and the influence of health-risk factors covering SES (like educational background) on multimorbidity [1, 2].

The findings were analysed using narrative synthesis due to the scarcity of relevant studies and the heterogeneity in exposures, outcomes, and methodologies across Southeast Asian research, which resulted in a broad range of multimorbidity prevalence estimates [1]. Despite these variations, the review identified key patterns in the relationship between education and multimorbidity. In some Southeast Asian studies, higher education appeared protective, possibly due to increased health awareness and better access to healthcare, while in others, it was associated with greater multimorbidity, potentially reflecting longer life expectancy and more frequent diagnosis among the better educated [1, 2]. Similar mixed associations have been observed in studies from other regions, such as South Asia, where the direction of relationship between education and multimorbidity also varies depending on context [1]. However, our own empirical analysis using TCS data did not find a statistically significant association between education and multimorbidity. This lack of a clear relationship further

supports the notion that the impact of education on multimorbidity is highly context-specific, likely shaped by intersecting factors such as health system access, socio-economic inequality, and diagnostic practices [2, 3]. These findings underscore the need for more regionally grounded and methodologically consistent research on the social determinants of multimorbidity.

11.3 Common clusters of chronic conditions/multimorbidity patterns

Chapters 5 and 8 examined the common patterns of multimorbidity using both prevalence-based analysis and latent class analysis (LCA). The prevalence-based analysis revealed that metabolic syndromes (obesity, hypertension, and hyperlipidaemia) were the most common patterns of multimorbidity in Thailand, particularly among men, and people aged over 60 years old. The latent class analysis (LCA) further supported these findings by identifying three distinct multimorbidity patterns which were “Metabolic syndromes,” “Cardiometabolic disorders,” and “Multi-system conditions.” Both analyses highlight the significant influence of demographic factors, especially age and sex. For example, older individuals were more likely to develop multi-system conditions, while metabolic syndromes and cardiometabolic disorders were more common in men. These complementary findings strengthen the understanding of how age and sex shape multimorbidity patterns in Thailand.

Age is a major factor in multimorbidity, with older individuals showing a higher prevalence of multimorbidity [4]. However, gender differences are also critical in shaping these patterns. In this study, men were more likely to develop multimorbidity, but other studies suggest that women are at higher risk [4]. This discrepancy may be since the chronic condition clusters in the Thai Cohort Study (TCS) do not include mental health disorders, and that women in the study had higher educational attainment compared to the general female population in Thailand [4, 5]. Recent research indicates that men tend to experience physical multimorbidity, such as cardiometabolic disorders, while women are more susceptible to multimorbidity related to mental health. These gender differences could be influenced by genetic, hormonal, and social factors [4, 5]. Additionally, higher education levels have been associated with greater attention to personal health, which may help explain some of the observed differences [2, 4, 5]. Therefore, stratifying studies by sex and age is crucial for a more nuanced understanding of how demographic characteristics contribute to multimorbidity patterns across different populations.

11.4 Risk factors for multimorbidity

Chapters 5 and Chapter 6 and Chapter 8 demonstrated that the prevalence of multimorbidity among participants in TCS was about 10%. Moreover, the older the participant, the higher the prevalence was, and that prevalence is higher in men than in women.

Chapter 6 showed that poor dietary habits including the preference of fast food and instant food, alongside erratic sleep schedules, are associated with a heightened likelihood of developing multimorbidity. These findings were similar to other studies [6, 7]. In Thailand, dietary patterns have been rapidly changing over the past few decades, with a transition towards more processed foods, higher sugar intake, and less consumption of traditional nutrient-dense meals [6, 7]. Coupled with increasingly sedentary lifestyles, these changes are contributing to rising rates of obesity, hypertension, and metabolic disorders. When combined with irregular sleep patterns, these factors collectively affect metabolism and the endocrine system, which may significantly increase the cumulative risk of chronic diseases and multimorbidity [6]. These trends suggest that if current dietary habits and lifestyle choices continue, Thailand could face a growing burden of multimorbidity in the future, with implications for public health policy and healthcare systems [6, 7].

Nevertheless, engaging in regular exercise, which includes household chores, mitigated the risk of multimorbidity as found in Chapter 6 and Chapter 8. This finding was consistent with other research [8, 9]. Housework is a form of incidental exercise and may help reduce the risk of multimorbidity, as physical activity benefits cardiovascular health by lowering blood pressure, cholesterol, and aiding weight control [8, 9]. Therefore, urging people to change their bad habits, eat less fast food, get regular sleep, be physically active, and especially promoting housework and gardening are feasible for effectively controlling the prevalence of multimorbidity and its related patterns [6].

11.5 Spatial distribution of multimorbidity

Chapter 7 and Chapter 8 conducted spatial analyses to identify geographic distribution of multimorbidity in Thailand. Age-adjusted prevalence of multimorbidity was notably higher in developed regions like Bangkok and its metropolitan areas. On the other hand, certain economically disadvantaged provinces in southern Thailand exhibited a lower prevalence of multimorbidity. Furthermore, hot spot analysis indicated that clusters of high prevalence were

concentrated in Bangkok and its surrounding metropolitan regions, contrasting with predominantly cold spot distributions in southern Thailand. As for the geographic distribution of latent class of chronic conditions, the high age-adjusted prevalence of “Cardiometabolic disorders” class tended to be clustered in central Thailand.

The prevalence of multimorbidity and its associated patterns would be elevated in densely populated regions characterized by higher regional household incomes and longer average educational attainment, notably in urban centres like Bangkok and central Thailand. This suggested a positive correlation between multimorbidity prevalence and wealth [10, 11]. While socioeconomic disadvantage typically correlated with heightened multimorbidity prevalence due to adverse living conditions and restricted healthcare access, research showed contradictory trends in more developed and affluent regions, particularly in LMICs [10, 11]. In these contexts, superior healthcare infrastructure and higher living standards coincided with stress, unhealthy lifestyle factors including sedentary behaviour, and poor dietary habits, contributing to increased multimorbidity [10-12]. Moreover, reliance on healthcare services and polypharmacy among individuals of higher socioeconomic status (SES) may exacerbate this phenomenon [11-13].

11.6 Mortality and multimorbidity

Chapter 9 shows that over a 15-year period from 2005 to 2019, multimorbidity was associated with a 43% higher risk of all-cause mortality. Furthermore, individuals burdened with multimorbidity who were older, had lower SES and engaged in unhealthy lifestyle practices such as irregular sleep patterns, smoking, and alcohol consumption face an even greater risk of mortality.

In terms of socio-demographic elements, age played a significant role in determining multimorbidity, with older individuals facing heightened mortality risks due to increased prevalence of multiple conditions and age-related mortality. Female participants generally exhibited higher survival rates, regardless of multimorbidity status, possibly attributed to genetic variances, differences in healthcare-seeking behaviours, and gender-specific disease susceptibilities [14, 15]. Other research has also shown that higher levels of education and income are linked to decreased mortality risks, reflecting the protective influence of SES on health outcomes [16]. Urbanization further reduced mortality risks, indicating the health

advantages associated with socioeconomic progress, which was similar to one study in USA [17].

As for the lifestyles, excessive sleep duration, particularly exceeding 9 hours per day, was associated with elevated mortality risks, particularly among individuals with multimorbidity. This may be attributed to disruptions in endocrine function and metabolism, exacerbating chronic conditions [18]. However, regular consumption of foods containing soybeans and engagement in housework are associated with reduced mortality risks, highlighting the protective effects of dietary habits and physical activity [14]. Both smoking and alcohol consumption elevate mortality higher risks in populations with multimorbidity, primarily due to cardiovascular diseases (CVD) and related cancers [19]. These findings underscore the significance of lifestyle modifications in mitigating mortality risks across diverse populations.

11.7 The prevention and management of multimorbidity

Chapter 10 showed that despite predominant focus on individual chronic conditions in health policy and health care in Southeast Asia, the escalating prevalence of multimorbidity, particularly amidst an aging population, is progressively drawing attention. Consequently, there is a great interest in policy research concerning multimorbidity in the region. However, it should be noted that although there is a growing body of research on multimorbidity in the region, there remains a gap in translating these findings into actionable measures.

Efforts to prevent multimorbidity should focus on improving health literacy through education, as higher literacy aids disease management [20]. Singapore shows the success of community-based health education [21]. Moreover, taxing tobacco, alcohol, and sugary drinks is also key. Studies show sugar taxes reduce consumption and improve health, while tobacco taxes help reduce smoking [22, 23]. Addressing social determinants of health like poverty is critical, as disparities contribute to multimorbidity [24]. Universal Coverage Schemes (UCS) in Southeast Asia could improve health outcomes for the people [25]. Collaboration with stakeholders like the World Health Organization (WHO) and the Association of Southeast Asian Nations (ASEAN) is essential for large-scale initiatives [20]. The ASEAN's framework on sweet beverages is an example of successful regional cooperation [26].

Regarding management strategies, it is essential to adopt integrated care models that focus on patient-centred primary care. This approach ensures coordinated care across various

providers, addressing the diverse needs of individuals with multimorbidity. Active patient involvement in care plans is crucial to improve adherence and outcomes [20, 27].

Additionally, optimizing medication management is key to reducing polypharmacy. Regular medication reviews can help minimize unnecessary medications, prevent drug interactions, and enhance communication between healthcare providers [28]. Finally, utilizing digital health technologies, such as telemedicine and mobile health apps, can improve multimorbid patient monitoring, enable timely interventions, and enhance access to care, particularly for individuals in remote areas [29].

Future research should employ evidence-based decision-sharing methodologies, particularly in augmenting healthcare infrastructure and personnel and in developing pertinent policies, which is crucial to overcome challenges such as the prevailing focus on single chronic diseases, resource constraints, healthcare workforce shortages, and individual adherence issues [27, 30]. Ultimately, the overarching goal of these endeavours is to improve the quality of life and promote favourable health outcomes for individuals across Southeast Asia.

11.8 The strengths and limitations

11.8.1 The strengths

The main advantage of this thesis is that the primary data source is a large-scale study of population health in Thailand, which covers an extensive age range, and has a national population distribution. This is the first time Thai Cohort Study (TCS) has been used to study multimorbidity. Another strength is that this thesis also addresses multimorbidity from many perspectives to provide a holistic understanding of this health challenge in Thailand and Southeast Asia more broadly. It comprises a systematic review discussing the relationship between multimorbidity and education, a cross-sectional study of the patterns of multimorbidity and related health-risk factors, spatial analysis for the geographical distribution of the prevalence of multimorbidity, survival analysis to understand the mortality risk of multimorbidity and its related factors, and finally the discussion and outlook on the prevention and management of multimorbidity [31, 32].

This thesis was a pioneering effort to investigate the prevalence and patterns of multimorbidity in Thailand using age and sex stratification in the TCS. At the same time, this thesis is also the first attempt to explore patterns and clustering of chronic conditions in

multimorbidity applying latent class analysis (LCA) in TCS. In addition, we also used as many relevant risk factors (socio-demographic and health-behaviour elements) as possible to explore their connection with multimorbidity, to gain a more comprehensive understanding of multimorbidity. Innovative use of spatial analysis and TCS data enriches the explanation of multimorbidity prevalence in Thailand, facilitated the development of targeted interventions, and increased public awareness through spatial visualizations such as hotspot maps. This thesis was also able to assess 15 years of follow-up mortality risk using official Thai government (Thai Ministry of Interior), which has a high degree of accuracy [33]. This enabled the examination of a broad long-term view of the impacts of multimorbidity.

11.8.2 The limitations

There are several major limitations in this thesis that should be acknowledged. Firstly, most analyses were cross-sectional, which precludes establishing causal relationships between age, gender, other risk factors, and multimorbidity. Secondly, the data collection in 2013 may not fully reflect current multimorbidity patterns, potentially affecting the generalizability of the findings [31, 32]. Thirdly, the TCS did not collect information on mental health or disease severity, limiting the comprehensiveness of our analysis. Fourthly, the cohort demographics, while having a similar median age to the general Thai population, were skewed towards younger and more highly educated individuals, meaning the sample does not fully represent the broader population. Fifthly, chronic conditions were self-reported, which could introduce recall bias; however, validation studies have shown these measurements to have high sensitivity and specificity [31-33].

Additionally, the study relies on a single dataset from one country (Thailand), which limits the direct generalizability of the findings to other Southeast Asian contexts. Differences in healthcare systems, socio-economic conditions, and population structures mean that the exact prevalence and patterns observed may not be directly applicable to other LMICs [31, 32]. Nevertheless, the study provides methodological insights and a framework that can inform research and policy development in similar contexts [32, 33].

Regarding spatial analyses, results may be confounded by unmeasured environmental and socio-economic factors, and limitations in district-level sociodemographic data posed additional challenges. While all-cause mortality was used as the primary outcome, future

studies could examine cause-specific mortality for a more nuanced understanding of multimorbidity impacts [14].

Finally, using secondary TCS data not specifically designed for multimorbidity research introduced additional constraints [31-33]. For example, weighting measures could not be applied, limiting the precision of prevalence estimates. Statistical methods such as factor analysis may not fully capture multimorbidity patterns [34, 35]. Additionally, longitudinal analysis across three survey waves (2005, 2009, 2013) may be affected by variations in disease assessment. Despite these limitations, the TCS data provide valuable insights into multimorbidity in Thailand, and all results are interpreted with these caveats in mind.

11.9 Direction for future research

To further build on the results of this thesis regarding multimorbidity in Thailand and Southeast Asia some future research directions are recommended. The priority is to establish a longitudinal database to identify life course risks and patterns unique to multimorbidity in today's Thailand as well as in Southeast Asia. Ideally, such data should be collected using objective methods such as health examination rather than subjective methods such as self-reporting. Studies should also adopt standardised definitions of chronic diseases and harmonised operational definitions of multimorbidity to mitigate selection bias and ensure more reliable and comparable estimates [36].

Longitudinal studies are essential because they allow for the identification of causal relationships between multimorbidity and health-risk factors over time, offering a more accurate understanding of how these factors interact and evolve. Unlike clinical-based approaches, which often capture only snapshots of data, longitudinal studies track changes in individuals' health over extended periods, providing a clearer picture of cause-and-effect relationships [37]. Additionally, these studies can account for variables such as gender and age stratification, particularly in research on multimorbidity associated with metabolic syndrome. Moreover, the use of spatial analysis alongside longitudinal data enhances the understanding of the geographical distribution of multimorbidity, factoring in environmental, socio-economic, and lifestyle elements to provide a more comprehensive overview. This combined approach supports the development of targeted public health strategies and interventions [14, 38].

In addition to studying all-cause mortality, future studies should also explore the relationship between cause-specific mortality and multimorbidity [14]. Furthermore, policy research on multimorbidity should be strengthened by thoroughly analysing the current situation and burden of multimorbidity in the Southeast Asian region, with a focus on the pragmatic implementation of policies rather than their mere theoretical articulation [20]. Moreover, cutting-edge research could incorporate studies on genetic predisposition to multimorbidity and epigenetic patterns, which suggest that the likelihood of developing chronic diseases may be influenced by inherited genetic factors or environmental exposures that affect gene expression over time [39]. The development of obesity [39] and hypertension [40] is significantly affected by epigenetics (modification of DNA), which in turn affects the development of their associated multimorbidity [41]. These aspects are crucial for a more comprehensive understanding of multimorbidity and its prevention.

11.10 The implications and contributions to public health

11.10.1 The implications

With an aging global population, multimorbidity is increasingly becoming a critical public health issue. LMICs with large aging populations, are facing a growing burden of multimorbidity. Yet, research in these regions remains relatively scarce. Understanding the patterns and determinants of multimorbidity is essential for effective healthcare planning, resource allocation, and the development of targeted prevention and management strategies to improve health outcomes and quality of life for affected individuals [42, 43].

This thesis presents a comprehensive study of multimorbidity in Thailand, offering valuable insights into its patterns and complexities in Southeast Asia. By examining the interactions between chronic diseases, this study enhances our understanding of how these conditions co-exist and impact individuals' health, forming the foundation for more effective healthcare programming and resource allocation [20]. For example, the high prevalence of clustered metabolic conditions, such as obesity, hypertension, and hyperlipidaemia, underscores the need for personalized approaches in managing individuals with multimorbidity. This emphasizes the importance of tailored medication strategies to reduce the risks of polypharmacy and adverse drug interactions in these patients [20, 44].

Beyond informing Thai health policy, the findings also provide a broader framework applicable to other LMICs with similar socio-economic and demographic characteristics. These countries often face comparable challenges, including rising multimorbidity prevalence, limited healthcare resources, and the need for evidence-based interventions. By synthesizing context-specific factors and demonstrating how multimorbidity patterns relate to demographic, socio-economic, and lifestyle determinants, this research offers practical guidance for designing prevention and management strategies in LMICs [1, 20].

While prior studies have pointed to socio-economic factors such as income, education, and healthcare access as influencing multimorbidity [2], our study did not find very conclusive evidence directly linking these factors to multimorbidity patterns in Thailand. This highlights the need for further research using larger datasets and more refined methods to explore socio-economic influences more comprehensively [44, 45]. Nevertheless, our findings confirm the significant association between smoking, unhealthy diet, and irregular sleep patterns with an increased likelihood of developing multimorbidity. Recognizing these risk factors supports the development of targeted strategies to prevent and manage multimorbidity, which is informative for LMICs facing similar health transitions [46, 47].

11.10.2 The contributions

The findings of this thesis provide valuable information for public health systems to better understand and manage multimorbidity in clinical practice. This may include the development of clinical guidelines and decision support tools to offer comprehensive care for individuals with multiple chronic conditions. Understanding patterns of multimorbidity enables the guiding of resource allocation within primary healthcare systems, ensuring that resources flow to areas of greatest need and improving the efficiency and effectiveness of healthcare delivery [45].

In addition, multimorbidity research provides evidence to support the development and implementation of public health interventions aimed at preventing and managing chronic diseases, including multimorbidity. Evidence-based decision-making enhances the effectiveness of interventions and improves population health outcomes [46-48]. By defining and incorporating disparities in the geographic distribution of multimorbidity, this research also informs strategies to advance health equity, including promoting equitable access to healthcare and addressing social determinants of health [47]. For policymakers and program

managers, these findings highlight priority areas for investment and system-level reforms. For public health professionals, the evidence identifies modifiable risk factors that can be targeted through prevention and health promotion activities. For epidemiologists and healthcare professionals, the results provide population-level insights that can guide clinical practice and integrated care planning [45, 47].

Importantly, while these contributions are based on Thailand's experience, the findings offer practical insights for other LMICs facing similar demographic, socio-economic, and health system challenges. Countries with aging populations, increasing urbanization, and shifts in lifestyle-related risk factors can draw upon the lessons from Thailand to inform context-specific policies, optimize healthcare resource distribution, and implement targeted prevention and management strategies [47, 48]. Finally, for future researchers, this thesis highlights important knowledge gaps, including the inconclusive role of socio-economic factors and the need for longitudinal and multi-level analyses, which remain critical for advancing the field of multimorbidity research [46-48]. Thus, this thesis not only strengthens Thailand's public health evidence base but also provides transferable knowledge to guide LMICs in addressing the growing burden of multimorbidity.

11.11 The Conclusion

This thesis contributes to the growing body of knowledge on multimorbidity in Thailand and Southeast Asia by examining its prevalence, patterns, and socio-demographic determinants. The findings underscore the high prevalence of metabolic syndrome, particularly the clustering of obesity, hypertension, and hyperlipidaemia, as critical drivers of multimorbidity in the region. Age, gender, and lifestyle factors including poor dietary habits and sedentary behaviour were found to be significant contributors to the development of multimorbidity, with older adults and men showing higher susceptibility.

These findings highlight the pressing need for targeted prevention and management strategies, specifically addressing the components of metabolic syndrome, as well as the socio-demographic factors influencing multimorbidity. The study advocates for the integration of spatial analyses in healthcare resource allocation, enabling tailored interventions for high-prevalence areas, which could improve early detection and treatment outcomes. Moreover, this

thesis emphasizes the importance of moving beyond single-disease paradigms, promoting a comprehensive, patient-centred approach to managing multiple chronic conditions.

Future research should prioritise the development of longitudinal, population-based datasets, with standardized definitions and stratification by age and gender, to better understand the long-term trends and determinants of multimorbidity. Further spatial analyses are needed to map risk factor distributions and guide evidence-based policy decisions. Additionally, research focusing on the implementation of effective multimorbidity management strategies, including the integration of digital health tools and optimized medication management, will be crucial for reducing the burden of multimorbidity in Thailand and Southeast Asia.

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Appendixes

The Appendix 1: Conference presentation

Feng X, Kelly M, Sarma H. **The association between educational level and multimorbidity among adult in Southeast Asia: A systematic review.** *National Centre for Epidemiology and Population Health (NCEPH) student conference, College of Health and Medicine, Australian National University, Canberra, Australia, October 12, 2021.*

Feng X, Sarma H, Bagheri N, Thinkhamrop K, Suwannatrai AT, Seubsman S, Sleigh A, Kelly M. **Multimorbidity in Thailand: Disease burden, mortality, and geographic distribution.** *The 10th International Conference on Public Health (ICOPH 2024), Bangkok, Thailand, August 15-16, 2024.*

The Appendix 2: The ethical report and the questionnaires of the Thai Cohort Study (TCS)

The official ethical clearance report, along with relevant supporting documentation, is provided in Appendix 2. This appendix also contains detailed information about the background of the Thai Cohort Study (TCS), including the study design, participant recruitment, and ethical review process. These materials demonstrate that all procedures complied with established research ethics standards and provide transparency regarding the governance and approval process of the study.

In addition, Appendix 2 includes comprehensive descriptions of the data collection procedures and the survey instruments used in the TCS. It also presents the principal investigators and research team members, thereby fulfilling the requirement for researcher background information and offering a complete overview of the methodological and ethical foundations of the study.

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Application Form

Created by: **u6453474**
Record number: **13087**
Protocol type: **Expedited Ethical Review (E1)**
Protocol number: **2021/796**

Date entered: **23/11/2021**
Ethics program type: **Postgraduate**
Requested start date: **01/01/2022**
Requested end date: **30/11/2024**

Protocol title: **Multimorbidity in Thailand: Disease burden, mortality, and geographic distribution**

Investigators

Name	Role	Department
Bagheri, Nasser	Supervisor	Centre for Mental Health Research, CHM Research School of Population Health, ANU
Feng, Xiyu	Primary investigator	SCHOLAR - AG RTP Stipend Scholar - CMBE, OTH Scholarships, ANU
Kelly, Matthew	Supervisor	Department of Global Health, CHM Research School of Population Health, ANU
Sarma, Haribondhu	Supervisor	Department of Global Health, CHM Research School of Population Health, ANU

Investigators Detailed

Name: Bagheri, Nasser **Role:** Supervisor

Expertise: Dr. Bagheri holds a Ph.D. from University Of Otago in New Zealand. He is an expert in spatial analysis and epidemiology of non-communicable diseases. As the supervisor of the research, he can make many important instructions for research development and methods of spatial analysis.

Name: Feng, Xiyu **Role:** Primary investigator

Expertise: I am the Ph.D. candidate of population health at the Australian National University. My study would collaborate with the Sukhothai Thammathirat Open University (STOU) in

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Thailand, which is to address the disease burden, mortality, and geographic distribution of multimorbidity in Thailand.

Name: Kelly, Matthew **Role:** Supervisor

Expertise: Dr. Kelly holds a Bachelor of Asian Studies and a Ph.D. in Population Health. He is a researcher in the Global Health Department at the Australian National University. He is also committed to the study of public health in Thailand. As the primary supervisor of the study, he will provide many important instructions and materials for this research.

Name: Sarma, Haribondhu **Role:** Supervisor

Expertise: Dr. Sarma holds a Ph.D. from the Australian National University. He is also an expert in data analysis and the establishment of health system in developing countries. As the supervisor of the research, he can make many important instructions for the methodology of the research.

External Investigators

Name	Role	Institution
Thinkhamrop, Kevin	Supervisor	Khon Kaen University

External Investigators Detailed

Name: Thinkhamrop, Kevin **Role:** Supervisor

Expertise: Dr. Thinkhamrop holds a master's degree in public health and a PhD. in public health. He is a visiting fellow from the Khon Kaen University in Thailand. As another supervisor of this study, he will also provide important guidance for this research since this is the study. He is also an experienced biostatistician who can provide his expertise in the data analysis.

Departments

Primary	Department	Faculty
No	Centre for Mental Health Research	CHM Research School of Population Health
Yes	Department of Global Health	CHM Research School of Population Health

HUMAN RESEARCH ETHICS COMMITTEE

Application Form

Project Questions Detailed

Description of Project

Describe the research project in terms easily understood by a lay reader, using simple and non-technical language. Multimorbidity is generally defined as the coexistence of two or more chronic conditions in a person. Multimorbidity is a condition that increases in prevalence with age and is more common in people over the age of 60. Common patterns of multimorbidity are predominantly non-communicable diseases (NCDs), especially NCDs that older adults are prone to such as cardiometabolic multimorbidity with a predominance of cardiovascular and metabolic chronic conditions. Mental-physical multimorbidity, which is a combination of psychological and physical disorders, is also more common nowadays. Thailand has been undergoing a health transition in recent years. Because of increasing aging, NCDs such as stroke and ischemic heart disease have replaced infectious diseases such as cholera and malaria in causing the largest disease burden in Thailand. However, the prevalence, incidence, and associated factors of multimorbidity in Thailand are not fully understood. Moreover, as in many less developed regions, there is also a lack of guidelines of prevention and treatment for multimorbidity in Thailand.

The Thai Cohort Study (TCS) is a nationwide project, which aims at investigating health risk transition since the country is shifting from the traditional infectious disease model to the emerging chronic diseases. This project started in 2005 and has recruited 87 134 individuals who enrolled at Sukhothai Thammathirat Open University (STOU) in Thailand. Participants in this study came from all over the country, aged 15-87 years. These respondents were a reasonable representation of the STOU student body and the general Thai population since their median age, median income, national residence, and ethnic diversity were similar to the national population structure. Approximately 40,000 of these participants were followed up in 2013.

The TCS also includes mortality data. This is a very important part of the TCS. The mortality data has been counted to the year 2020. It is one of the most valuable aspects of the TCS data. By analysing this data, it is possible to study the increased risk of all-cause mortality and the cause-specific mortality rate of people with multimorbidity. And it also can be found which combinations of conditions lead to the highest risk of death. This is of interest for effective prevention and treatment of multimorbidity in Thailand.

The purpose of this research is to address the prevalence, incidence, and associated factors causing multimorbidity, can contribute to more effective protection and management. It can also help local governments to develop more appropriate policies for the prevention and treatment of multimorbidity.

Location of Data Collection

Australia No

Overseas Yes

Provide country / area where data collection will be conducted The data sources are

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derived from the Thai cohort study, which were collected between 2005 and 2013 by the Sukhothai Thammathirat Open University (STOU) in Thailand.

Aims of the Project

List the hypothesis and objectives of your research project. The aim is to understand the current status of multimorbidity in Thailand, especially the most common pattern of multimorbidity, namely, the most common cluster of chronic conditions, the changes in the prevalence, incidence and mortality of multimorbidity, the associated major risk factors, and geographic distribution in Thailand in order to help local governments to develop and promote policies to prevent and treat multimorbidity, thereby improving the quality of life of the Thai population.

Objectives and hypothesis

1) To identify the common patterns of multimorbidity in Thailand.

There is no uniform pattern of multimorbidity. Most studies have been of clusters of common chronic diseases, including combinations of chronic diseases common to older adults, such as cardiometabolic multimorbidity with combinations of cardiovascular and metabolic conditions, and physical and mental multimorbidity. For this Objective the most common disease combinations will be identified in various age and sex groups. This information is critical to planning health systems to address complex health challenges.

2) To understand the change of prevalence, incidence, and mortality, and related risk or protective factors of multimorbidity in Thailand.

Thailand is undergoing a health transition from communicable to NCDs, and multimorbidity is becoming more prevalent. Through this objective, I will analyse the changes in prevalence of multimorbidity and the factors associated with the incidence of multimorbidity in Thailand from 2005 to 2013. As for the mortality, I will analyse the increased risk of all-cause mortality, as well as the mortality rate of multimorbidity and the associated factors, and which patterns of multimorbidity lead to the highest risk of mortality. These multimorbidity-related factors are included in baseline risk factors in TCS including underlying diseases, individual lifestyle factors, and sociodemographic factors.

3) To analyse the geographic distribution of multimorbidity in Thailand.

In this objective, I will analyse the variation of geographic distribution of multimorbidity in Thailand to determine the distribution of multimorbidity in Thailand due to regional characteristics. These regional characteristics could include socioeconomic differences, urban areas versus rural areas, and different direction such as south and north part of Thailand [12]. Differences in multimorbidity between urban and rural areas, and economically developed and less developed areas will be ascertained to better find ways to prevent multimorbidity and to plan health system response.

Methodology

In language appropriate for a lay reader, explain why the methodological approach minimises the risk to participants. (For surveys, include justification of the sample size).

Because the data used in this study is secondary data, it does not involve direct data collection and management. The data that will be provided from the Thai cohort study. This means there is no risk to participants of their being identified through this study.

The Thai Cohort Study (TCS) is a nationwide project, which aims at investigating health risk transition since the country is shifting from the traditional infectious disease model to the emerging chronic diseases. This project started in 2005 and has recruited 87 134 individuals who enrolled at Sukhothai Thammathirat Open University (STOU) in Thailand. Participants in

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this study came from all over the country, aged 15-87 years. These respondents were a reasonable representation of the STOU student body and the general Thai population since their median age, median income, national residence, and ethnic diversity were similar to the national population structure. Nevertheless, they would be younger and more educated than the most adults in Thailand and the proportion of STOU students who living in urban area was also relatively higher. Thus, TCS members not only represented the development of the Thai population in the future, they were also in a more advanced position on the path of the transition of health risks. The data collection was from three mail-out questionnaires.

Provide the survey method, a list of the questions to be asked or an indicative sample of questions. These should give a good sense of the most intrusive/sensitive areas of questioning. 1) To identify the common patterns of multimorbidity in Thailand.

The definition of multimorbidity needs to be clarified first and differentiated from comorbidity in order to identify the types of chronic conditions common to multimorbidity, namely, the pattern of multimorbidity. Multimorbidity and comorbidity are easily confused. Comorbidity emphasizes the occurrence of one disease leading to the existence of other diseases, and there is a primary and secondary distinction in terms of conditions, but no such concept for multimorbidity. For example, cardiovascular diseases (CVDs) and obesity are comorbidities of diabetes, implying that diabetes is a predisposing factor for these conditions and that people with diabetes are more likely to develop them than the general population. In addition, because there are no uniform standards for patterns of multimorbidity, it is common practice to include common conditions or diseases with high morbidity, making it easy to obscure comorbidity with multimorbidity. Therefore, it is necessary to clarify the definition and patterns of multimorbidity in the study.

The chronic conditions included in the patterns of multimorbidity differ depending on the subject of the research. There is no uniform pattern of multimorbidity, but all patterns are based on the topic of study. How the patterns are established requires a review of common chronic conditions. The main review includes Thai Cohort Study (TCS) on the types of chronic conditions and published literature related to chronic conditions, the guidelines issued by the local government on chronic conditions, and published literature on chronic conditions and multimorbidity outside of TCS. Thai hospital data are not comprehensive at this stage, the TCS is the main focus here. 18 NCDs were included in the TCS as baseline in 2005. 6 types of cancer were included, and the remaining 7 metabolic and cardiovascular NCDs, including diabetes and stroke, were the focus of this study, excluding cancer. These diseases could constitute cardiometabolic multimorbidity. This is because of health transition that is occurring in Thailand. The common chronic conditions in Thailand have evolved from infectious diseases such as cholera and malaria to common NCDs in the elderly such as stroke and ischemic heart disease. However, infectious diseases such as HIV and Tuberculosis (TB) are still common chronic conditions in Thailand. The data on infectious chronic diseases such as TB are available in the TCS. Thus, it is also essential to be aware of the impact of infectious chronic conditions when determining the pattern of multimorbidity. TB complicating diabetes is now very common, and this condition is a comorbidity rather than a multimorbidity. Accordingly, when analysing multimorbidity, attention should be paid to the presence of a causal association to the diseases, as distinguished from comorbidity. Additionally, TCS has data on mental health such as depression/anxiety which could be included in mental-physical multimorbidity (mental disorders combined with physical illness). The most appropriate multimorbidity pattern should be selected according to the study topic. Nowadays, multimorbidity patterns based on NCDs are the most common.

2) To understand the change of prevalence, incidence, and mortality, and related risk or

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protective factors of multimorbidity in Thailand.

With Objective 1), after determining the pattern of multimorbidity, this Objective can be calculated and analysed by TCS. The TCS is an eight-year-long cohort study with three nodes, 2005 (baseline), 2008/09 (midpoint), and 2013 (endpoint). The calculation of the prevalence of multimorbidity (cross-sectional study) at these three nodes (odd ratio (OR), Logistic regression) can be used to identify the factors that influence multimorbidity. Furtherly, the incidence (cumulative incidence) of multimorbidity and the protective and risk factors of multimorbidity are obtained through the calculation and analysis of cohort studies (rate ratio (RR), Poisson regression); if the outcome of multimorbidity being rare, RR replacing by OR (Logistic regression)). Regarding the analysis of mortality, the TCS mortality data is one of the most valuable aspects of the TCS. We will use the survival analysis (hazard ratio (HR), Cox regression) since survival analysis is often used to define disease mortality, it is well suited for use here to analyse mortality caused by multimorbidity in TCS. Using this part of the data it is possible to study the increased risk of all-cause mortality, what factors increasing or decreasing the mortality of multimorbidity, mortality from different causes in those with multimorbidity, and which patterns of multimorbidity resulting in the highest risk of death.

As for protective or risk factors associated with multimorbidity, since there are many disease-related factors in the TCS, we should select and classify these factors before studying multimorbidity. Based on the data in the TCS, factors that affect chronic conditions including NCDs can also have an impact on multimorbidity. These factors could be divided into several categories.

The first category is socio-demographic factors (List A in 2005 baseline questionnaire: You and Your Home). As for the elements of demographics, gender, age, marital status, and residence status may have some influence on multimorbidity. Although some studies have shown that females in Thailand are more likely to develop multimorbidity, the prevalence of multimorbidity is higher in males than in females according to the TCS analysis and it is still inconclusive whether gender directly affects the risk of multimorbidity. The age factor is one of the most important factors influencing multimorbidity, as aging is positively associated with multimorbidity. Marital status is also unclear for the study of multimorbidity. Place of residence, which includes urban and rural areas and different cities and regions, directly affects the living environment, which in turn may affect multimorbidity. These factors can be explored and summarized by Objective 3), an analysis of the association between geographic factors and multimorbidity. As for socio-economic status (SES), it includes factors such as income and education. The relationship between multimorbidity and SES could be complex. In high-income countries (HICs), there would appear to be a largely negative (or inverse) relationship between the odds of multimorbidity and SES. However, studies in some low-middle-income countries (LMICs), including Thailand, have shown a positive association between the likelihood of multimorbidity and SES. Such contradictory results have also been found with respect to education and income factors. It is widely believed that in both HICs and LMICs, people with low SES are more likely to suffer from multimorbidity because they lack health literacy and stress in burdening health and nutritious food has reduced their health status. In addition, their inability to afford high medical costs after developing multiple diseases leads to further deterioration of their health status. The lack of studies may cause the conclusion that higher SES increases the odds of developing multimorbidity. Furthermore, in LMICs, people with higher SES would tend to have a sedentary lifestyle, which may increase the chances of developing multimorbidity. They also have better access to medical care and better health knowledge and are more likely to be diagnosed and reported as having chronic conditions. Shortly, the relationship between SES and multimorbidity needs to be analysed in more longitudinal studies. TCS is a very good choice to study the relationship between multimorbidity and SES.

The second category would be health status (List C in 2005 baseline questionnaire: Your Health, Injures and Health Service Use). People with chronic conditions such as obesity,

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diabetes and CVDs such as hypertension and stroke are more likely to develop multimorbidity, as has been shown in other studies involving multimorbidity in Thailand. This may be due to the comorbidity of these conditions. However, when conducting studies, multimorbidity and comorbidity are completely different studies and should be distinguished. The clear point is that comorbidities have primary and secondary conditions, whereas multimorbidity does not. Currently, in the case of TCS, the focused pattern of multimorbidity studied is dominated by cardiometabolic multimorbidity.

Personal lifestyle should be the third category (List E in 2005 baseline questionnaire: Food and Physical Activities and List F in baseline questionnaire: Tobacco, Alcohol and Transport). Many studies from other countries have shown that lifestyles that have an impact on chronic diseases also have influence on multimorbidity. Smoking, alcohol consumption, physical inactivity, and diets high in oil, salt, and sugar may all contribute to multimorbidity, especially in the elderly population. However, such studies are still rare in Thailand. Personal lifestyles are distinctive in different countries due to social, economic and cultural differences. For example, the staple food of Thais is mainly rice, which is like many Asian countries, but far from Western countries. These may all have some influence on multimorbidity. Therefore, further research via TCS is needed to address the association between personal lifestyles and multimorbidity in Thailand.

3) To analyse the geographic distribution of multimorbidity in Thailand.

The purpose of this study was to assess the variation in the prevalence of multimorbidity and its relationship with associated factors in different regions of Thailand through TCS using geographic information systems (GIS). TCS collected address information of participants, which provided data for spatial analysis using GIS. The related factors of spatial analysis included regional factors such as south, east, north, and west, urban versus rural, social-environmental factors like education, income, residence, and occupation, and personal lifestyle factors including smoking and alcohol consumption, exercise, and diet (List A, C, E, F in 2005 baseline questionnaire).

Spatial analysis, especially hotspot analysis of multimorbidity is necessary. This is because studies have confirmed that there are differences in the status of multimorbidity between less developed and developed regions. The incidence and prevalence of multimorbidity are not only related to individual genetic factors, but also to socio-environmental factors such as population density, urbanization and family SES, as well as individual lifestyles such as diet and exercise. These socio-environmental factors and individual lifestyles are closely related to geographic distribution. Hotspot analysis is one of the perfect methods to understand the geographic distribution of multimorbidity since hotspot analysis can be used to identify clusters of multi-morbid people and analyse what factors in their geographic location can be contributing. In recent years, although there have been some studies on the relationship between multimorbidity and social environment in Thailand, studies that use hotspot analysis to show the relationship between them are still very rare. Therefore, it is interesting to analyse the geographic characteristics of multimorbidity in Thailand through TCS.

It is useful to understand these differences of geographic distribution for the prevention and treatment of multimorbidity. Local indication of spatial autocorrelation (LISA) and local Morans I would be the commonly used spatial analysis methods that were applied to analyse the spatial distribution in this objective. Pearson correlations will be used to assess the correlation between the prevalence of multimorbidity in each province in Thailand and related socio-environmental factors and individual lifestyles.

What mechanisms do the researchers intend to implement to monitor the conduct and progress of the research project? For example:

How often will the researcher be in touch with the supervisor?

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Is data collection going as expected? If not, what will the researcher do?

Is the recruitment process effective?

How will the researcher monitor participants' willingness to continue participation in the research project, particularly when the research is ongoing? Secondary data from Thai Cohort Study would be used in this research, for which data collection has been completed in Thailand. No further data collection will take place with this population there is no risk of participants no longer being willing to participate. This study only focused on data analysis from 2005 to 2013. Mortality data in TCS is updated in 2020.

The researchers will communicate with the supervisor team, at ANU, about the progress of the research every two weeks. Also one academic staff member at Sukhothai Thammathirat University

will help supervise the analysis and data access. All data are already collected and being held at the Australian National University.

Participants

Provide details in relation to the potential participant pool, including:

target participant group;

identification of potential participants;

initial contact method, and

recruitment method. The Thai Cohort Study (TCS) is a nationwide project, which aimed to investigating a health risk transition since the country is shifting from the traditional infectious disease model to the emerging chronic diseases. This project started in 2005, when a mail-out questionnaire was sent to all enrolled students at Sukhothai Thammathirat Open University (STOU) in Thailand (n=200,000), 87 134 individuals responded and this group forms the baseline cohort. Participants in this study came from all over the country, aged 15-87 years. The data collection was from three mail-out questionnaires. The first was in 2005 (baseline), with follow-up surveys in 2009 and 2013. At each round of follow-up around 70% of the cohort were retained in the study. This meant that around 40,000 participants completed the final 2013 follow-up. Periodically the TCS database participants details are shared with the Ministry of Public Health, who match with their mortality database and provide the TCS investigators with details in including date and cause of death. This study will use this information but the Investigator will not be provided with the Citizen Identification Numbers.

Proposed number of participants 87134

Provide details as to why these participants have been chosen? Participants in the Thai Cohort Study (TCS) came from all over the country, aged 15-87 years. These respondents were a reasonable representation of the STOU student body and the general Thai population since their median age, median income, national residence, and ethnic diversity were similar to the national population structure. TCS members not only represented the development of the Thai population in the future, they were also in a more advanced position on the path of the transition of health risks.

Cultural and Social Considerations/Sensitivities

What cultural and/or social considerations/sensitivities are relevant to the participants in this research project? This is no cultural and/or social considerations/sensitivities are relevant to the participants in this research project since this study uses secondary data. Thai academics designed and carried out the original data collection.

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Incentives

Will participants be paid or any incentives offered? If so, provide justification and details.

No

Benefits

What are the anticipated benefits of the research? The research will provide a deeper understanding of the current status of multimorbidity in Thailand, especially the most common pattern of multimorbidity, namely, the most common cluster of chronic conditions, the changes in the prevalence, incidence and mortality of multimorbidity, the associated major risk factors, and geographic distribution in Thailand.

To whom will the benefits flow? Thai health policy makers, planning programs and policies to control and treat multimorbidity.

Informed Consent

Indicate how informed consent will be obtained from participants. At least one of the following boxes MUST be ticked 'Yes'.

In writing Yes

Return of survey or questionnaire Yes

Orally No

Other No

If Oral Consent or Other, provide details.

Confidentiality

Describe the procedures that will be adopted to ensure confidentiality during the collection phase and in the publication of results. This study uses secondary data and it does not involve sensitive information. The ANU researchers will not be provided with any identifying information. Therefore there is no way that confidentiality could be breached. The entire process would be monitored by the supervisors in ANU and the Thai cohort study Team in Thailand.

Data Storage Procedures

Provide an overview of the data storage procedures for the research. Include security measures and duration of storage. The primary data of this study are stored at the ANU and STOU in Thailand. The entire process of analysis would be monitored by the supervisors in ANU to ensure the security of the data. The secondary de-identified data will be stored on encrypted hard drive by the primary researcher.

Feedback

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Provide details of how the results of the research will be reported / disseminated, including the appropriate provision of results to participants. If appropriate, provide details of any planned debriefing of participants. Research results will primarily be reported in the researchers thesis document. Research results will also be shared with researchers at the Thai Cohort Study team who will then share them with the Ministry of Public Health. If the research results are published or disseminated, it would be in collaboration with the Thai Cohort Study team in Thailand.

Any further contact with participants will be carried out by the Thai Cohort Study team not this researcher. Research results are may also be published or disseminated in peer reviewed journal articles, in collaboration with the Thai Cohort Study Team in Thailand. As participants are not being identified to the researcher no debriefing or feedback will be relevant to this study. Any participant contact is the responsibility of the Thai Cohort Study team.

Supporting Documentation

Have you uploaded all relevant supporting documentation, such as Participant Information Sheet and/or consent form, to the documents tab?

No

Has this work been approved by another Human Research Ethics Committee (HREC)? No

If yes, please give the name of the approving HREC. You will also need to include a copy of the approval letter in your application and also upload an electronic copy to the Documents tab. Ethical approval for data collection between 2004 and 2014 was obtained from Sukhothai Thammathirat Open University Research and Development Institute (protocol 0522/10) and the Australian National University Human Research Ethics Committee (protocols 2004344 and 2009/570). No data has been collected since then.

Funding

Is this research supported by external funding? No

Provide the name/s of the external sources of funding. Please include grant number/s if available. Data collection between 2005 and 2013 was supported by the International Collaborative Research Grants Scheme with joint grants from the Wellcome Trust UK (GR071587MA) and the Australian NHMRC (268055) and by a global health grant from the NHMRC (585426).

This current research project does not have any external funding.

Is the research conducted under the terms of a contract of consultancy agreement between the ANU and the funding source? No

Describe all the contractual rights of the funding source that relate to the ethical consideration of the research.

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High Risk One Summary

Question	Answer
Is this a clinical trial?	No
Does this research involve the intentional recruitment or issues involving Aboriginal and / or Torres Strait Islander Peoples?	No

High Risk Two Summary

Question	Answer
Does this research involve Human Genetics?	No
Does this research involve Human Stem Cells?	No
Does this research involve Women who are pregnant and the Human Foetus?	No
Does the research involve people highly dependent on medical care who may be unable to give consent?	No
Does the research involve people with a cognitive impairment, an intellectual disability or a mental illness?	No
Does this research involve an intention to study or expose or is likely to discover illegal activity?	No
Does this research involve human gametes (eggs or sperm)?	No
Does this research involve excess ART embryos?	No

Expedited Questions Summary

Question	Answer
Third Party Identification	No
Children or Young People	No
Dependent or Unequal Relationship	No
Membership of a Group, or Related Issues	No
Physical Harm	No
Psychological Harm (includes Devaluation of Personal Worth)	No
Social Harm	No
Economic Harm	No
Legal Harm	No
Covert Observation	No
Deception	No
Sensitive Personal Information	No

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Question	Answer
Overseas Research	Yes
Secondary Data	Yes
Collection, use or disclosure of personal information WITHOUT the consent of the participant	No

Questions Detailed

Overseas Research Yes

Will the research be conducted in a politically stable country? Yes

Will details of a Local Contact be provided for participants to contact after the researcher has left the area? Yes

Will there be appropriate reporting back to the community and/or a direct flow of benefits to the community? Yes

Have you read all of the above questions? Yes

Secondary Data Yes

Is this publicly available data? Yes

Are the risks easily negated, minimised or managed?: No

In 200 words or less, outline the measures which will be taken to address the risks*:

Secondary data from Thai cohort study would be used in this research, for which data collection has been completed in Thailand. No further data collection will take place with this population there is no risk of participants no longer being willing to participate. This study only focused on data analysis from 2005 to 2013 and the related mortality data in Thai cohort study in 2020.

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Supporting Documentation

Please ensure electronic copies of the supporting documentation have been uploaded into the documents tab of your protocol

These may include (please circle the relevant answer):

List of indicative questions	Y/ ☒ N
Copy of questionnaire / survey	☒ Y/N
Invitation or introductory letter/s	☒ Y/N
Publicity material (posters etc.)	☒ Y/N
Information sheet	☒ Y/N
Consent form	☒ Y/N
External approval documentation	☒ Y/N
Research visa (if applicable)	Y/ ☒ N
Other (specify below)	Y/ ☒ N

For other, please specify:

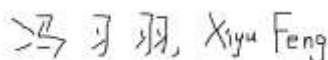
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SIGNATURES AND UNDERTAKINGS

PROPOSER OF THE RESEARCH

I certify that all the persons listed in this protocol have been fully briefed on appropriate procedures and in particular that they have read and are familiar with the national guidelines issued by the National Health and Medical Research Council (the National Statement on Ethical Conduct in Human Research 2007).

I certify that the above is as accurate a description of my research proposal as possible and that the research will be conducted in accordance with the National Statement on Ethical Conduct in Human Research 2007. I also agree to adhere to the conditions of approval stipulated by the ANU Human Research Ethics Committee (HREC) and will cooperate with HREC monitoring requirements. I agree to notify the Committee in writing immediately of any significant departures from this protocol and will not continue the research if ethical approval is withdrawn and will comply with any special conditions required by the HREC.

 Xiyu Feng

Signed:.....

Date:.....17th Dec 2021.....

ANU SUPERVISOR

I certify that I shall provide appropriate supervision to the student to ensure that the project is undertaken in accordance with the undertakings above:

 M. Kelly

Signed:..... Date:.....17.12.21.....

AS FROM MONDAY 21ST OCTOBER 2013 THE SIGNATURE OF THE HEAD OF ANU DEPARTMENT/GROUP/CENTRE IS NO LONGER REQUIRED.

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

15 December 2004

Prof Adrian Sleight
National Centre for Epidemiology and Population Health
The Australian National University
ACT 0200

Dear Prof Sleight,

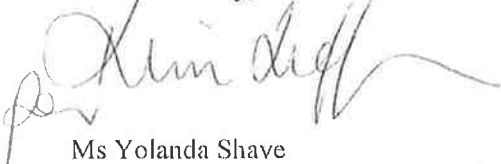
Protocol 2004/344
Thai Health-Risk Transition: A National Cohort Study

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,



Ms Yolanda Shave
Secretary, Human Research Ethics Committee

รับ
ทราบ
V. King
ดร. อภิสิทธิ์ เวชชาชีวะ
ธันวาคม 2004

FACULTY OF LAW
CANBERRA ACT 0200

TELEPHONE +61 2 6125 0454
FACSIMILE +61 2 6125 0150
EMAIL hilary.charlesworth@anu.edu.au



22 December 2003

Dr Adrian Sleight
NCEPH

Dear Dr Sleigh

ANU Protocol 255

I am writing to confirm that your application has been read by the ANU Human Research Ethics Committee. After examining the nature of the proposed research in the first phase (Phase 1a) of the project (in the first year), the HREC considered that it did not require ethics approval under the NH & MRC guidelines. As discussed with you, we look forward to receive a new application when you proceed to Phase 1b of the project.

Yours sincerely

May, Chae

Hilary Charlesworth

Chair, ANU Human Research Ethics Committee

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દાખલ
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สำเนา บันทึกข้อความ

ส่วนราชการ สถาบันวิจัยและพัฒนา ฝ่ายประสานงานการวิจัย โทร. ๒๑๘๗

ที่ พบ 0522.10(02)/1132

วันที่ 5

พฤศจิกายน 2546

เรื่อง แจ้งมติที่ประชุมคณะกรรมการวิจัย

เรียน รองศาสตราจารย์ ดร.เจ้าอาว สืบสมาน

ตามที่ท่านได้รับทุนสนับสนุนการวิจัยจาก Wellcome Trust เพื่อดำเนินการวิจัย เรื่อง "Thai Health Risk Transition : A National Cohort Study" (การเปลี่ยนผ่านปัจจัยเสี่ยงทางสุขภาพคนไทย : การศึกษาแบบโคฮอร์ตระดับชาติ) ร่วมกับ มหาวิทยาลัยแห่งชาติออสเตรเลีย (Australian National University) และ มหาวิทยาลัยควีนส์แลนด์ และได้เสนอให้ที่ประชุมพิจารณาแนวทางการวิจัยในคน และ แบบพหุวิธีแบบอินเทอมีเดียตด้วยความสนใจ นั้น

บัดนี้ คณะกรรมการวิจัยในการประชุม ครั้งที่ 6/2546 เมื่อวันที่ 8 ตุลาคม 2546 พิจารณาแล้วเห็นว่าโครงการวิจัยดังกล่าวเป็นโครงการที่มีขอบข่ายการดำเนินงานที่กว้างขวางมาก หากสามารถดำเนินการให้ประสบผลสำเร็จตามที่ตั้งใจไว้ จะต้องมีความรู้ในเรื่องสุขภาพของคนไทยซึ่งเป็นประโยชน์อย่างยิ่ง ที่ประชุมได้รับทราบด้วยความชื่นชมที่ผู้วิจัยได้ทำข้อเสนอให้กับมหาวิทยาลัย และ เห็นสมควรสนับสนุนการดำเนินการวิจัยดังกล่าวโดยมีประเด็นที่แนะนำผู้วิจัย ดังนี้

1. ควรมีระบบการบริหารจัดการโครงการ และระบบการบริหารด้านการเงิน โดยประสานงานกับมหาวิทยาลัยเนื่องจากเป็นโครงการวิจัยระยะยาว
2. ควรมีคณะทำงานต่าง ๆ ตั้งแต่ระดับนโยบายถึงระดับปฏิบัติการ โดยกำหนดองค์ประกอบและหน้าที่ของคณะทำงานให้ชัดเจนทั้งด้านวิชาการ และด้านการบริหารจัดการโครงการ ตลอดจนมีผู้บริหารเพื่อกำกับและติดตามให้เป็นไปตามขั้นตอนของงาน
3. ควรร่วมมือกับบุคคลและหน่วยงานต่าง ๆ ควรมีหลักประกันเพื่อให้งานประสบผลสำเร็จ และควรดำเนินการอย่างเป็นทางการ
4. ควรมีการเสนอข่าวสารเพื่อประชาสัมพันธ์ให้บุคลากรและหน่วยงานต่าง ๆ ได้ทราบเกี่ยวกับความเป็นมา แนวทางการดำเนินงาน ตลอดจนความก้าวหน้าของโครงการ โดยอาจมีสารรณรงค์เป็นระยะ เช่น 3 เดือน 6 เดือน
5. ควรมีการชี้แจงให้นักศึกษา มสธ. ที่จะดบเป็นตัวอย่าง จำนวน 100,000 คน ได้ทราบถึงขั้นตอนต่าง ๆ ของการให้ความร่วมมือกับการวิจัยในครั้งนี้ และควรพิจารณาว่าจะมีสิ่งจูงใจอะไรบ้างที่จะให้นักศึกษาเหล่านี้

จึงเรียนมาเพื่อโปรดทราบและโปรดดำเนินการในส่วนที่เกี่ยวข้องต่อไป

ลงชื่อ	ผู้อำนวยการสถาบันวิจัยและพัฒนา
เพื่อใช้ลงนาม	
ที่	
วันที่	
ที่	

(รองศาสตราจารย์ ดร.สุจิตต์ เวชกิจ)
ผู้อำนวยการสถาบันวิจัยและพัฒนา

รับ
ทราบ
Vthien
นายก อบจ. เชียงใหม่
๕ พ.ย. ๒๕๔๖

Certified Copy
Sam-ang Sribman



ATTACHMENT 1: English translation of STOU letter of approval

COPY (Internal Official Letter)

MEMORANDUM

Office Research and Development Institute, STOU Ph. No 3187

No. Edu 0522.10 (02)/1132 **Date** 5 November 2003

Title Informing the consensus of the research committee

Dear Associate Professor Sam-ang Seubsman

With reference to the Wellcome Trust Fund grant for collaborative research on “Thai Health-Risk Transition: A National Cohort Study” between Sukhothai Thammathirat Open University and Australian National University and Queensland University regarding the ethics and voluntary consent form.

Now, the research committee, of the 6/2546 the University Research Committee meeting, October 8, 2003 at Room 1514 level 5, Administrative Building: Sukhothai Thammathirat Open University, considered that the research project entitled “ Thai Health Risk Transition; A National Cohort Study” funded by Wellcome Trust to Associate Professor Dr. Sam-ang Seubsman under the cooperation with Australian National University and University of Queensland has a wide scope. If successful as planned it will be a benefit to the learning of Thai people.

The committee accepted with appreciation and approved the project.

Recommendation from the committee were to:

1. Establish administrative structure to manage to research project effectively by close cooperating with the university.
2. Establish related working groups in various levels from research strategies and practice with clear responsible tasks.
3. Cooperate with various divisions in the university to ensure the success of the project.
4. Create public relation within the university for the project procedure and progress by reporting 3 or 6 monthly report.
5. Inform STOU students for the research procedure for full cooperation.

Please accept and proceeding in accordance.

(Associate Professor Dusit Wechakit, PhD)
Director, Research and Development Institute



สำเนา บันทึกข้อความ

ส่วนราชการ สถาบันวิจัยและพัฒนา ฝ่ายประสานงานการวิจัย โทร.3187

ที่ ศธ 0522.10(02)/1132

วันที่ 5

พฤศจิกายน 2546

เรื่อง แจ้งมติที่ประชุมคณะกรรมการวิจัย

เรียน รองศาสตราจารย์ ดร.สำออง สืบสมาน

ตามที่ท่านได้รับทุนสนับสนุนการวิจัยจาก Wellcome Trust เพื่อดำเนินการวิจัย เรื่อง "Thai Health Risk Transition : A National Cohort Study" (การเปลี่ยนผ่านปัจจัยเสี่ยงทางสุขภาพคนไทย : การศึกษาแบบโคฮอร์ตระดับชาติ) ร่วมกับ มหาวิทยาลัยแห่งชาติออสเตรเลีย (Australian National University) และ มหาวิทยาลัยควีนส์แลนด์ และได้เสนอให้ที่ประชุมพิจารณาแนวทางการวิจัยในคน และแบบฟอร์มใบยินยอมด้วยความสมัครใจ นั้น

บัดนี้ คณะกรรมการวิจัยในการประชุม ครั้งที่ 6/2546 เมื่อวันที่ 8 ตุลาคม 2546 พิจารณาแล้วเห็นว่าโครงการวิจัยดังกล่าวเป็นโครงการที่มีขอบข่ายการดำเนินงานที่กว้างขวางมาก หากสามารถดำเนินการให้ประสบผลสำเร็จตามที่วางแผนไว้ จะต้องมีความรู้ในเชิงสุขภาพของคนไทยซึ่งเป็นประโยชน์อย่างยิ่ง ที่ประชุมได้รับทราบด้วยความชื่นชมที่ผู้วิจัยได้ทำชื่อเสียงให้กับมหาวิทยาลัย และเห็นสมควรสนับสนุนการดำเนินการวิจัยดังกล่าวโดยมีประเด็นที่แนะนำผู้วิจัย ดังนี้

1. ควรมีระบบการบริหารจัดการโครงการ และระบบการบริหารด้านการเงิน โดยประสานงานกับมหาวิทยาลัยเนื่องจากเป็นโครงการวิจัยระยะยาว
2. ควรมีคณะทำงานต่าง ๆ ตั้งแต่ระดับนโยบายถึงระดับปฏิบัติ โดยกำหนดองค์ประกอบและหน้าที่ของคณะทำงานให้ชัดเจนทั้งด้านวิชาการ และด้านการบริหารจัดการโครงการ ตลอดจนมีผู้บริหารเพื่อกำกับและติดตามให้เป็นไปตามขั้นตอนของงาน
3. การร่วมมือกับบุคคลและหน่วยงานต่าง ๆ ควรมีหลักประกันเพื่อให้งานประสบผลสำเร็จ และควรดำเนินการอย่างเป็นทางการ
4. ควรมีการเสนอข่าวสารเพื่อประชาสัมพันธ์ให้บุคลากรและหน่วยงานต่าง ๆ ได้ทราบเกี่ยวกับความเป็นมา แนวทางการดำเนินงาน ตลอดจนความก้าวหน้าของโครงการ โดยอาจมีการรายงานเป็นระยะ เช่น 3 เดือน 6 เดือน
5. ควรมีการชี้แจงให้นักศึกษา มสธ. ที่จะตกเป็นตัวอย่าง จำนวน 100,000 คน ได้ทราบถึงขั้นตอนต่าง ๆ ของการให้ความร่วมมือกับการวิจัยในครั้งนี้ และควรพิจารณาว่าจะมีสิ่งจูงใจอะไรบ้างที่จะให้แก่นักศึกษาเหล่านี้

จึงเรียนมาเพื่อโปรดทราบและโปรดดำเนินการในส่วนที่เกี่ยวข้องต่อไป

เสนอ	ผู้อำนวยการสถาบันวิจัยและพัฒนา
เพื่อโปรดทราบ	
ที่	
วันที่	
เรื่อง	
พิจารณา	

(รองศาสตราจารย์ ดร.ดุสิต เวชกิจ)
ผู้อำนวยการสถาบันวิจัยและพัฒนา

[Signature]
.....

Certified Copy
Sam-ang Seban

ENGLISH DRAFT



ENGLISH DRAFT
THAI HEALTH-RISK TRANSITION: A NATIONAL COHORT STUDY
INFORMATION SHEET FOR PARTICIPANTS

ATTACHMENT 3: INFORMATION SHEET

(THIS IS THE INVITATION LETTER AS WELL - TWO COMBINED INTO ONE)

Dear STOU student,

We invite you to be part of an exciting new project called the *Thai Health-Risk Transition: A National Cohort Study*, which is starting now (in 2005) and will be continued, with your input, throughout Thailand for the next few years and, hopefully into the future. With your participation, we will accumulate and analyse knowledge on the health of our people that will be help Thais and other populations in the future.

The Project

Thailand's disease patterns are changing. This is because socioeconomic development induces profound population changes in factors posing risks to our health. Some health changes are good but others, like emerging diabetes, heart disease and injuries, are of concern. Such a 'health transition' can be better understood if there is information on new causes of disease – immediate risks, and 'upstream' economic, cultural and environmental influences creating those risks. This health-risk transition is being studied in the whole Thai population – looking back 50 years, then forwards starting with this questionnaire sent to over 100,000 Sukhothai Thammathirat Open University students living all over Thailand. The study will map the changing health-risks and upstream influences, support PhD and post-doctoral training, inform preventive programs, boost regional research capacity and create a regional partnership between Thailand and Australia.

The project is led by STOU and the Australian National University (ANU). It involves more than 12 investigators from STOU, Chiang Mai University, the Thai Ministry of Public Health, the Thai National Economic and Social Development Board, the National Centre for Epidemiology and Population Health at ANU and, the University of Queensland. The research enables PhD training of 3 Thais and 2 Australians and creates opportunities that otherwise would not exist for staff at various levels in both countries. We aim to have a substantial long-term positive impact on Thai population health. The principal investigators are Associate Professor Sam-ang Seubsman at STOU and Professor Adrian Sleight at ANU. The other research team members are described on the website:

http://nceph.anu.edu.au/Thai_Cohort_Study/research_team.php

ENGLISH DRAFT

If you decide to participate, here are some questions and answers that may assist your decision:

What should I do before joining this Study?

- You will need to read and understand this **Information Sheet**, then sign the consent form **before** filling in the questionnaire. The consent form **and** your completed questionnaire **need to be returned together** in the envelope provided.
- Please **keep** this **Information Sheet** for your reference.

Can I change my mind once I have agreed to join the Study?

- Your participation in the study is voluntary and you may withdraw from the study at any time.
- You may contact the Chief Investigator or Chair of the STOU Research Committee if you have any queries or concerns about your involvement in the study (contact details are below).
- You can be assured that there is no actual or possible link with your academic progress at STOU if you are part of this Study, or, if you decide at any time that you wish to stop participating.

What happens to information I provide for the Study?

- The information you provide will be confidential. All personal data remain confidential and will never be released to any individual or organisation. Digital data will be stored by the researchers in password-protected computer file.
- All Study information will be stored in a locked area at Sukhothai Thammathirat Open University available only to the researchers involved in the project.
- The Sukhothai Thammathirat Open University research team will analyse the information gathered and may ask you to continue being part of the study after 2008 to gather more information about your health and lifestyle even if you are no longer a student at STOU.
- No individuals will be identified in the findings of the study. The study has received ethical approval from the President of STOU and the Human Research Ethics Committee at The Australian National University. If you have any concerns of an ethical nature or complaints about the manner in which the project is conducted, you may contact the Chair of the STOU Research Committee on Ph. 66 2 504 7587, Fax. 66 2 504 7780.

Please read and sign the consent form attached to the questionnaire if you would like to take part in the study **before** you answer any of the questions on the questionnaire. Your participation is voluntary and will involve you answering the questionnaire enclosed with this information sheet and other questions from time to time, which will be mailed to you via the STOU mailing system. If you choose not to participate, or you want to stop participating after joining the Study, your enrolment at STOU will not be affected in any way. (This is guaranteed by the Chair of the STOU Research Committee, the Study Investigators and the Human Research Ethics Committee at The Australian National University.)

For further information about the project, please contact Dr Sam-ang Seubsman at the Thai Cohort Study office at STOU, on Tel/Fax: 66 2504 7780, Email heasssam@stou.ac.th or visit our website: <http://www.stou.ac.th/ANU/>

Thank you for your time and co-operation and we look forward to your valuable contribution to this exciting project – the first of its kind at STOU and the largest such study ever undertaken in Thailand.

Yours sincerely,

Dr Sam-ang Seubsman, PhD
Principal Investigator
Room 101 Trisorn Building
Sukhothai Thammathirat Open University
Bangpood, Pakket
Nonthaburi 11120: Thailand
Tel/Fax. 66 2504 7780

Nuchjaree Kamolsukudom
Institute of Research & Development
Sukhothai Thammathirat Open University
Nonthaburi 11120 Thailand
Ph. 66 2 504 7587
Fax. 66 2 504 7780

From: Adrian Sleigh
Sent: Monday, 30 November 2009 2:14 PM
To: Matthew Kelly
Subject: ANU Human Ethics Protocol 2009/570 (Phase II)

-----Original Message-----

From: Aries
Sent: Monday, 30 November 2009 12:02 PM
To: Adrian Sleigh
Cc: Human Ethics Officer
Subject: Human Ethics Protocol 2009/570

THIS IS A SYSTEM-GENERATED E-MAIL. PLEASE DO NOT REPLY. SEE BELOW FOR E-MAIL CONTACT DETAILS.

Dear Prof Adrian Sleigh,

Protocol: 2009/570
Thai Health-Risk Transition: A National Cohort Study Phase II

I am pleased to advise you that your Human Ethics protocol received approval by the Chair of the Science and Medical DERC on 26/11/2009.

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. 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,

Kim

Ms Kim Tiffen
Human Ethics Manager/rDNA Committee Secretary Officer of Research Integrity Research Office Level 3 Innovations
Building 124 Eggleston Road The Australian National University ACTON ACT 0200
T: +61 2 6125 3427
F: +61 2 6125 4807
Kim.Tiffen@anu.edu.au or
human.ethics.officer@anu.edu.au
http://anu.edu.au/ro/ORI/Human/human_index.php

THIS DATA RELEASE AGREEMENT is made the 6th day of September, 2019

BETWEEN

**The Sukhothai Thammathirat Open University (STOU)
Thai Health-Risk Transition Office**

AND

**Xiyu Feng, Research School of Population Health, the Australian National University
(ANU)**

WHEREAS:

A. Sukhothai Thammathirat Open University (STOU), through its Thai Health-Risk Transition research, produced and holds certain data on its current and former students.

B. STOU is advised by the Data Access and Management Committee (DAMC) for this project, including data-managing investigators (Dr Vasoontara Yiengprugsawan, Dr Matthew Kelly, and Ms Wimalin Rimpeekool) on behalf of the project leaders (Associate Professor Sam-ang Seubsman, Professor Adrian Sleigh).

C. **Xiyu Feng** has expressed interest in evaluating specified aspects of the STOU data for the purpose of a collaborative research project; and

D. STOU agrees to provide its data to **Xiyu Feng**, on the terms and conditions set out in this agreement.

IT IS AGREED THAT

1. COLLABORATION

The STOU and **Xiyu Feng** are embarking on a collaborative project.

Staff managing the collaboration are:

- a) STOU – persons Ms Wimalin Rimpeekool representing A/Prof Sam-ang Seubsman
- b) Australian National University – persons Dr Vasoontara Yiengprugsawan and/or Dr Matthew Kelly representing Prof Adrian Sleigh
- c) **Xiyu Feng** and students under supervision. However, separate data agreements should be made with individual students and/ or collaborators if they are to be provided with access to the data.

A/P Sam-ang Seubsman and Prof A Sleigh have conceived the overall study, designed and conducted the surveys that produced the data, and edited and digitised the data as Principal Investigators. **Xiyu Feng** will work with one of the DAMC members (Dr Kelly,) representing data managing investigators and on behalf of A/Prof Seubsman and Prof Sleigh.

**Sukhothai Thammathirat Open University – Thai Health-Risk Transition
Project data release and use agreement with Xiyu Feng**

Confidential

Authorship of resulting papers should include at least **one** of the DAMC, representing Principal Investigators, Seubsman and Sleight. Where relevant other Thai Cohort Study or DAMC members may be invited as co-authors where they contribute substantially to the manuscript.

2. DATA PROVISION

It is hereby agreed that the STOU Thai Health-Risk Transition office will provide the *2005 baseline, 2009 follow-up, and 2013 follow-up data* from the Thai Health-Risk cohort research relevant to the research project specified by **Xiyu Feng**.

3. USE OF DATA

The STOU approves **Xiyu Feng** to use the data for the purpose of research and publication on the following only:

A study of incident cardiovascular disease in the Thai Cohort Study

If required **Xiyu Feng** may consult with other scientists on some issues (eg statistics), **if** appropriate, but will not provide them with access to data and will not transfer any data files to them. Other scientists may be included as co-authors if appropriate.

4. OWNERSHIP AND CONTROL OF DATA

The identity and content of the data will remain under the ownership and control of the STOU Thai Health-Risk Transition team.

5. STORAGE OF DATA

All data will be stored in a coded and confidential manner. The data should be stored in re-identifiable format but no names should be stored.

6. PROJECT RESULTS AND PUBLICATIONS

The results generated from this project will be given to the STOU Thai Health Risk Transition Office team (co-ordinated by A/Prof Sam-ang Seubsman and Ms Wimalin Rimpeekool) and the DAMC to comment and work on prior to release, including presentations. Any significant result from this project will be placed into the public domain via peer reviewed scientific journals. The level of contribution to the project will determine the positions of the authors on any manuscript.

7. COMMERCIALISATION

Commercial use of any knowledge emanating from this project is not intended. If a commercial use did emerge, the intellectual property rights to that would rest totally in the public domain as already agreed with the Wellcome Trust.

8. RETURN AND DISPOSAL OF DATA

Sukhothai Thammathirat Open University – Thai Health-Risk Transition
Project data release and use agreement with **Xiyu Feng**

Confidential

Xiyu Feng, agrees that, upon written request from STOU or its Thai Health Risk Transition Office, **Xiyu Feng** will promptly deliver (or destroy if so instructed) all data, materials and other items obtained from or supplied on behalf of the STOU under this agreement together with any copies thereof.

9. NO REPRESENTATIONS OR WARRANTIES

(a) Although the STOU will endeavour to include, in the data, information, which it believes to be relevant for the purposes for which it is being submitted, **Xiyu Feng** hereby acknowledges that neither the STOU nor its affiliates make any representation or warranty as to the accuracy or the completeness of the data.

(b) **Xiyu Feng** further acknowledges that the STOU and any of its employees, representatives or advisors expressly disclaim any and all liability to **Xiyu Feng** or ANU or any of its representatives or advisors for any possible damage (including any caused by negligence) resulting from the use of the data.

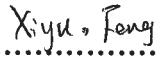
10. TERM

This Agreement will become effective as from the date first mentioned above and will remain in force until **31/12/2019**. The term of this agreement may only be extended with written agreement of the STOU and **Xiyu Feng**.

11. JURISDICTION

This Agreement shall be governed and construed in accordance with the laws of The Australian Capital Territory and Thailand.

EXECUTED AS AN AGREEMENT:

Signed for and on behalf of the Disclosing Party by:			
Signature: Full name: Ms Wimalin Rimpeekool representing A/Prof Sam-ang Seubsman (Principal Investigator), Sukhothai Thammathirat Open University	Date:	Signature:  Full name: <u>Dr Matthew Kelly</u> and/or Dr Vasoontara Yiengprugsawan representing Professor Adrian Sleight (Principal Investigator), The Australian National University	Date: 6/9/19.....
Signed for and on behalf of the Receiving Party by:			
Signature:  Full name: Xiyu Feng	Date:	Signature:  Full name: Pitawan Kuekthong (Witness)	Date: 6/9/19.....

Sukhothai Thammathirat Open University – Thai Health-Risk Transition
Project data release and use agreement with Xiyu Feng

Confidential

What is the Thai Health Research Project

The Thai Health Research Project or “the Thai Cohort Study” is the largest ongoing longitudinal cohort study in Thailand. The project is examining the causes of and risks for health problems and disease in the Thai population and assessing the most effective ways of protecting the health of Thai people. The project observes how lifestyles, environment, societal factors, cultural factors, geography and other factors interact and influence health.

The students of Sukhothai Thammathirat Open University have been the most important factor leading to the success of this project already through contributing their valuable time to filling out our questionnaires. At this time we ask for your cooperation again in filling out this 2013 questionnaire and returning it in the included pre-stamped envelope to the Health Research Project office. Your continued participation in this study however is completely voluntary and is solely aimed at improving population health in Thailand. Your participation will have no effect on your academic results at STOU.

What are the benefits provided by the Thai Health Research Project?

The Thai Health Research Project is finding effective ways to promote good health for Thai people which are appropriate for the Thai culture and society.

How can you contact the Thai Health Research Project?

The Thai Health Research Project has received ethical approval from both Sukhothai Thammathirat Open University and the Human Research Ethics Committee of the Australian National University.

If you have any questions or concerns about the project you can contact us at:

Associate Professor Sam-ang Seubsman
Director Thai Health Research Project
Room 101 Trisorn Building
Sukhothai Thammathirat Open University
Phone: 02-504-7780; www.stoucohort.com; email: tcs@stoucohort.com

Centre for Special Research Projects, Research Development Institute, Sukhothai Thammathirat Open University: 02-504-7590

Human Ethics Officer, Human Research Ethics Committee, Australian National University:
human.ethics.officer@anu.edu.au



COHORT PROFILE

Cohort Profile: The Thai Cohort of 87 134 Open University students

Adrian C Sleigh,^{1*} Sam-ang Seubsman,² Chris Bain³ and the Thai Cohort Study Team[†]

How did the study come about?

Public health researchers from Thailand's Sukhothai Thammathirat Open University (STOU), Chiang Mai University, Ministry of Public Health and National Economic and Social Development Board, and two Australian universities (Australian National University and University of Queensland) are collaborating to study the Thai health-risk transition. The project was funded by the International Collaborative Research Grants Scheme developed by the Wellcome Trust (UK) and the National Health and Medical Research Council (Australia). These 5-year grants stimulated regional research collaboration and capacity-building for significant public health topics.

One component of the research involves analysis of historical multi-level health risks and demographic and health outcomes over the last 50 years;¹ this study refined our conceptual model as the work progressed (Figure 1). A second component is post-graduate training for three Thais and two Australians to research aspects of the health-risk transition for PhDs, and for four Thais based at STOU to complete

Master degrees on related topics. The third component is a large national cohort study of health risks and outcomes among nationally dispersed STOU students.

Emergence of the Thai population from a traditional subsistence to modern consumer economy has already produced a demographic transition in birth and death rates (Figure 2).^{2,3} An epidemiological transition is also underway with disease patterns now beginning to resemble those in Western countries, reflecting the socioeconomic and environmental transformations and associated changes in risks to health (Table 1).⁴ These transitions involve shifts in social and cultural health-related behaviour due to absorption of scientific ideas on disease prevention and treatment, rising expectation of child and adult survival and increased investment in children, collectively referred to as the 'health transition'.^{5–7} Some health transition outcomes are welcome, such as falling mortality due to reproduction and infection; but other transition components are of concern, including chronic and degenerative diseases that were rare before and now appear with ever-increasing frequency. Countries undergoing such substantial changes need to analyse the progress and determinants of both risks and outcomes—the 'health-risk transition'.

Altering the distribution of health risk factors within whole populations is often the best target for interventions because it leads to the largest possible overall effect.^{8,9} Health planners should understand local dynamics of influential risk distributions and their upstream determinants before devising risk-focused national interventions. For example, chronic disease and injury are emerging as unfamiliar sources of most of the years of healthy life now being lost in Thailand. Rapid changes in lifestyle are evident with adoption of fast food and high fat diets and high exposure to traffic injury risks travelling by motorcycle or car without helmets or seat belts. Cancer, injury, cardiovascular disease, obesity and diabetes are responsible for a growing proportion of the disease burden.¹⁰

What does it cover?

We study the health-risk transition in a large cohort of Sukhothai Thammathirat Open University students

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† The members of the Thai Cohort Study team are:

Thailand: Duangkhae Vilainerun,² Suwanee Khamman,⁴ Boonchai Somboonsuk,⁵ Tippawan Prapamontol,⁶ Jaruwan Chokhanapitak,² Pathumvadee Somsamai,² Suttinan Pangsap,² Janya Puengson² and Daoruang Pandee²

Australia: Lynette Lim,¹ Tord Kjellstrom,¹ Anthony J. McMichael,¹ Jane Dixon,¹ Cathy Banwell,¹ Bruce Caldwell,¹ Gordon Carmichael,¹ Sharon Friel,¹ Lyndall Strazdins,¹ Emily Banks,¹ Tanya Mark¹ and Tarie Dellora¹

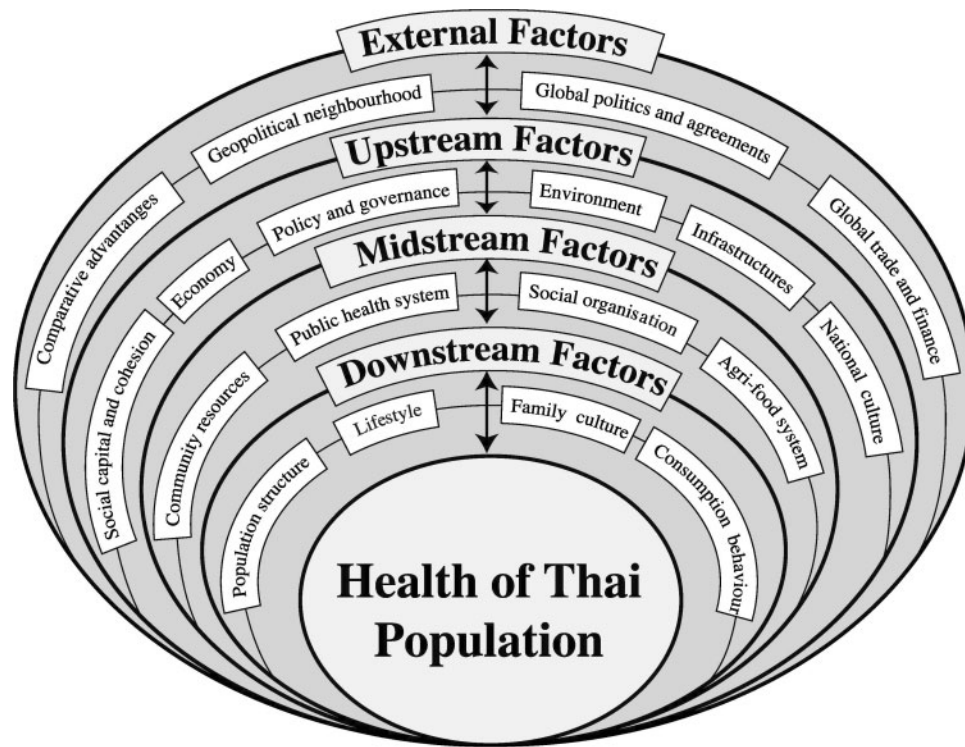
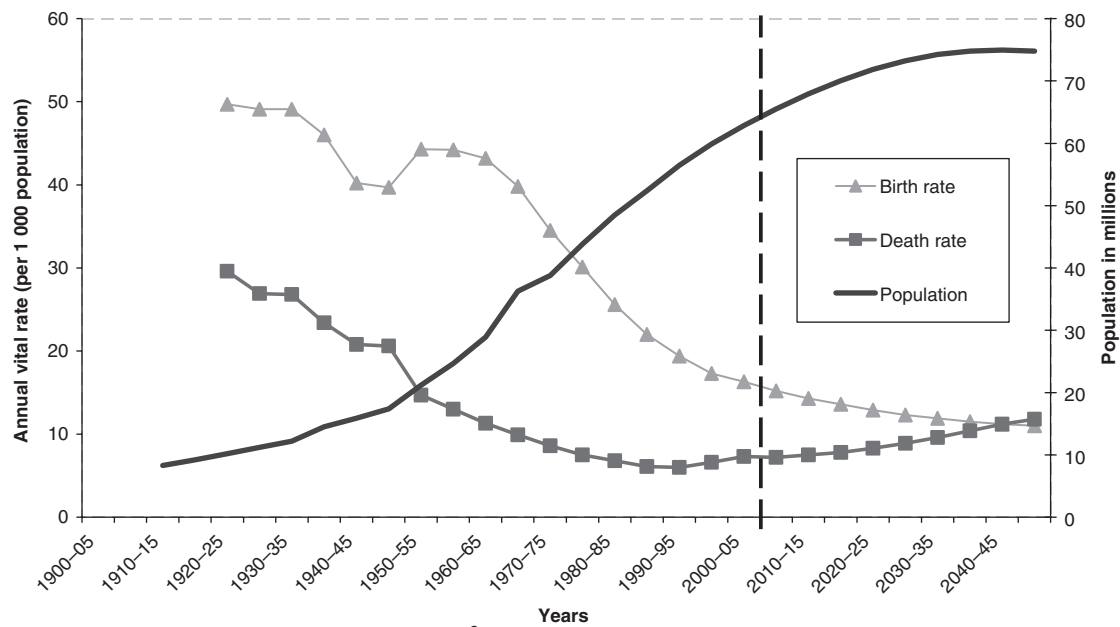


Figure 1 Multi-level model adopted for the Thai Health-Risk Transition Study



Sources: (before 1940, population) Hirschman, C (1994)².
 (before 1950) Crude birth and death rates adapted from estimates for each year during the period 1920–1950, Economic and Social Commission for Asia and the Pacific, 1976³.
 (from 1950) Source: Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2006 Revision, <http://esa.un.org/unpp/> (Thailand - viewed 23/05/2007)

Figure 2 The demographic transition in Thailand

Table 1 Leading causes of death in Thailand per 100 000 persons in 2003

Leading cause of death	Order	Male	Female	Total
External cause of morbidity and mortality, other accidents, including late effect	1	118.8	28.0	73.0
Neoplasm	2	81.3	57.4	69.3
Certain types of infectious and parasitic diseases	3	81.1	54.2	67.6
Diseases of the circulatory system	4	58.1	43.5	50.8
Diseases of the respiratory system	5	46.9	25.4	36.1
Diseases of the digestive system	6	22.7	10.7	16.4
Diseases of the genito-urinary system	7	16.3	16.5	16.4
Endocrine, nutritional and metabolic diseases	8	9.3	14.3	11.8
Disease of the nervous system	9	11.5	7.1	9.3
Disease of the blood and blood-forming organs and certain disorders involving the immune mechanism	10	1.2	1.2	1.2

Source: Health Information Group, Bureau of Health Policy and Strategy, Thailand.

Last data update: February 4, 2004, *ICD Mortality Tabulation, List1, the 10th Revision*. Data shown here adapted from Rukumnuaykit (2006).

living throughout Thailand, followed initially for four years (2005–09). We pose the following questions:

1. How are health-risks changing over time (i.e. the 'risk transition') both downstream (e.g. work stress, physical living conditions, personal life-style) and upstream (e.g. related to economy, infrastructure) for the Thai population.
2. How do the above risk distributions and transitions vary among sub-groups (e.g. drink-driving or fast food rates for those recently urbanized, or better educated, or with higher income, or by occupation or demographic categories).
3. How do changing multi-level risks and disease or injury patterns relate to each other?
4. What evidence-based interventions are needed and feasible in Thailand to substantially reduce avoidable emerging disease burdens?

Who is in the sample?

A broadly focused 20-page questionnaire, information sheet and consent form was mailed out to approximately 200 000 STOU students throughout Thailand from April to November 2005, reaching all those who

had completed at least their first semester. The research project paid return postage and by February 2006 a total of 87 134 had returned completed questionnaires and consent forms (44%).

STOU students are an accessible and informative group of emerging educated Thais, those most affected by risk and health transitions underway. This is because they reside all over Thailand and have a modest socio-economic status. Many are rural dwellers and most have full time jobs; their tertiary education has played an important role in Thai development for more than 25 years. As an open university, STOU enrolls over 200 000 students each year and those reaching a second or subsequent semester tend to complete their studies. Overall, 60% of students finish their degrees and those that do take on average about 7 years. They are charged nominal fees for enrolment, mailed course materials, seminars, TV broadcasts, newsletters and examinations. University lecturers travel countrywide for course seminars each semester and supervise all examinations. STOU maintains mail contact with its huge student body, processing voluminous materials daily. Towards the end of their degree all students come to stay on campus for 4 days of final sessions.

The return of 87 134 20-page questionnaires weighing 10 tonnes created a massive data processing task. The work was conducted onsite at STOU with a team of more than 20 staff from Khon Kaen University and STOU. Data were scanned using Scan Devet intelligent character recognition software developed in Thailand to create a linked image and digital file for each questionnaire. Each day 50 megabytes of encrypted image and digital data were uploaded by internet to offsite verification teams located upcountry at Khon Kaen; they compared scanned images and resulting digital data for accuracy and made necessary corrections. Overall, the 421 primary variables were recorded well for most questionnaires. Error rates for scanning were low but still amounted to a substantial correction task given nearly 37 million unique images and associated digital records. There were 509 variables in the cleaned master data set finalized by December 2006. A video of the questionnaire preparation, distribution and promotion, and subsequent data processing, is available in both English and Thai at <http://stoucohort.com>.

What has been measured?

Whenever possible, we used questions that had been standardized and validated, such as the Medical Outcomes (SF8) instrument and three CES-D anxiety-depression questions. To develop the questionnaire we created panels to work on various components, including demography and family, work, health services, disease and injury, social factors, environment, food and physical activity, tobacco, alcohol and transport. After many drafts

Table 2 Data collected in the STOU cohort baseline questionnaire

Section	Questionnaire headings
A	You and your home
B	Income and work
C	Your health, injuries and health service use
D	Social networks and well-being
E	Food and physical activity
F	Tobacco, alcohol and transport
G	Your family

the questionnaire was translated and further developed in Thai, piloted, and eventually back-translated to ensure meanings were stable.

The final 20-page document was divided into seven sections (Table 2). The first section recorded address and postcode, socio-demographic details, education, ethnic links and details on the domestic environment and household goods now and when aged 12 years. The next section dealt with occupation, income and stresses, autonomy and physical dangers or discomforts at work. The third section covered height, weight now and at birth, whether breast fed, vision and hearing now and as a child, dental health, symptoms of anxiety and depression, history of any one of 25 important diseases, self-reported general health (SF8), detailed injury history, health insurance and health services used and forgone. The next section covered social networks, trust levels, religion, spiritual health, sense of well-being and satisfaction. The fifth section covered food sources, preferences and intake, exercise and physical activity. The sixth section records habits with tobacco and alcohol, and use of transport, including safety aspects such as seat belts, helmets and drink-driving. The last section was on aspects of the respondent's family—survival or cause of death of parents, size, age and breast-feeding history of youngest child, type of family pets (if any) and allergy or asthma among any of the children.

How often have they been followed up?

So far there has been no individual follow-up but there have been many study team activities to help follow-up succeed in 2008. These build on the high response rate for the baseline round which reflected an array of strategies that worked well and will be further developed for the next stage. In the first year, after data collection (2006), there were 40 communications prepared by the team to describe aspects of the study or give related health information. These included 26 short articles in the Education Supplement of Khom Chadluek, a national broadsheet newspaper used to reach STOU students. As well there were appearances of the Thai study leader (SS) on STOU TV, detailed articles on the study in STOU

quarterly newsletters sent to every student, additional articles in other newspapers, and an explanatory video for the study website linked to the main web site for STOU. In 2007, the anti-attrition strategy includes direct feedback to each cohort member, mailing a diary after Thai New Year and including information on some preliminary results of the study, on first aid, and on management of snake bite (topics of interest). This 2007 mail-out will test strategies for contacting the cohort and will also include a short questionnaire for a 10% sample of cohort members on injury, mental health and internet use. The questionnaire will enable the team to test incidence measurements for two health problems with high event rates and of interest to the Ministry of Public Health. Experience gained with follow-up of a 10% sample in 2007 will help the team prepare for follow-up of the whole cohort in 2008.

What has the study found?

The analysis of the baseline data will take some time and at present is proceeding on several lines (including cancer, injury, environment, food and activity, social capital). Here, we present some information on the characteristics of the cohort compared with the Thai population, on some of the transitions they have experienced at home, and on the effects of rural or urban settings when young and now on body weight (Tables 3 and 4).

The STOU cohort members in 2005 were mostly in the third and fourth decade of life, with a median age of 29 years and an age range of 15–87 years. There was a slight excess of females (54.3%). Half the cohorts were still living in rural areas and almost all were Buddhist. The main regions of Thailand were well represented. For all these important attributes (and many others) the cohort represents the Thai population well, and this extends to the modest incomes with a median below US\$3000 per year.

Life histories of disease diagnosed by a doctor show well the mixed transitional patterns already present in the cohort (Table 3). Highest in frequency ($\geq 8\%$) were a modern degenerative problem (high cholesterol) and an important infection (dengue). Other 'modern' problems were apparent like high blood pressure, asthma and anxiety, as well as problems from pre-transition times (like malaria and TB). Injury was a widespread problem, with nearly one quarter (22%) reporting injuries that required medical treatment in the previous 12 months: 29% of these injuries were related to road traffic, 26% occurred at home and 14% were due to sport. Nearly 70% of traffic injuries were due to motorcycles, and 70% of these injuries were as the rider.

Cohort members have participated in the ongoing urbanization process underway in Thailand. Thus, 48.3% are living in a rural location now compared with 75.8% when they were 10–12-years old (about

Table 3 Baseline characteristics of the STOU cohort participants compared to the population of Thailand

	STOU Cohort	Thailand
Population	87 134	60 606 947
Median age (years)	29.0	29.2
Female (%)	54.3	51.2
Urban residence (%)	51.8	31.1
Buddhist religion (%)	94.5	94.2
Median income (US\$) ^a	2 550	2 742
Region (% of population)^b		
Bangkok	17.2	10.4
Central	30.6	23.3
North	18.2	18.8
Northeast	20.9	34.3
South	13.1	14.0
Age structure (% of population)^c		
20–29	52.3	24.9
30–39	32.3	23.9
40–49	12.9	21.6
50+	2.5	30.5
Disease ever diagnosed by doctor (%)		
High cholesterol/high lipids	8.7	N/A
Dengue	8.0	
Arthritis	5.9	
High blood pressure	4.6	
Asthma	3.8	
Liver disease (not cancer)	3.6	
Goitre/thyroid	3.5	
Depression/anxiety	3.4	
Malaria	2.5	
Diabetes	1.1	
Tuberculosis	0.9	
Cancer	0.8	

Source: figures for Thailand from the 2000 Thai Population and Housing Census, National Statistics Office, http://web.nso.go.th/eng/en/pop2000/prelim_e.htm, accessed May 2, 2007. However age data are for 2005 from the US Census Bureau, International Data Base (IDB) Summary Demographic Data for Thailand, <http://www.census.gov/cgi-bin/ipc/idbsum.pl?cty=TH>, accessed May 1, 2007.

^aBased on an exchange rate of 40 Baht per US dollar in 2005. Data for Thailand relate to 2004.

^bBased on a cohort subset of 86 425 persons reporting geographical location. The eastern region is included with the central region in the Thai census and this analysis.

^cBased on cohort subset of 84 612 persons aged ≥ 20 years.

18 years before the 2005 baseline, given the median age was 29 years). So in the last two decades, one quarter of the cohort members have moved from country to city. Over this same time period they have

experienced a very large transition in domestic environments, with the arrival of electricity, refrigerators, television, video-CD and mobile telephones for almost everybody (Table 4). As well mosquito netting or air conditioning has reached most cohort members, and safe water supplies (non-surface) have reached almost everyone. These changes in domestic 'hardware' have transformed the physical and information environment and we can be sure they are having powerful and diverse effects on health.

One finding that we will report here is the effect of sex and urbanization on body weight (Table 4). STOU females are far less overweight, and far more underweight than their male counterparts. In the Thai population, females are a little more overweight than males so these STOU females are quite exceptional. But the STOU males are quite similar to males in the general Thai population for the proportions overweight. The overweight rates for both sexes also relate to their location at age 10–12 years. Those who lived in rural areas at this formative age are substantially less overweight now as young adults (average 29-years old) than those who were urbanized at age 10–12 years, and this is notable for both sexes.

The transition from a rural to an urban environment influenced many health-related behaviours. For example, fast food and soft drink intakes were highest among those always urbanized, and next highest for those who urbanized since age 10–12 years. An opposite trend occurred for fruit and vegetable intake, with lower intakes for city dwellers. Exercise levels also fell with urbanization, while smoking and drinking rates rose. Those who were urban now and as children had higher rates of high blood pressure and depression, less trust, less use of social networks and poorer self-reported overall health.

What are the main strengths and weaknesses?

The strength of this study is that the cohort is large and is not confined to a single sex, profession or location. Also, the cohort represents the Thai population well making it a truly national study likely to be generalizable. Another strength of the study is the array of information collected allowing us to track exposures at multiple levels and (eventually) to assemble health-risk models that may capture more of the causal web than is usually possible. As well, a cross-cultural research team enriches the study.

One important area that could not be investigated with this cohort study is sexual health and behaviour. Obviously, we could not place such questions on a mailed questionnaire without facing unsolvable ethical problems, including the need to keep answers confidential within the household before they were sent back. Such privacy would be out of our control

Table 4 Selected cohort comparisons for transitions experienced since aged 10–12 years

Household goods	Proportion with goods (%)	
	When aged 10–12 years (N = 86 621)	Now (N = 86 681)
Electricity-outside line	70.3	89.3
Microwave oven	2.3	30.9
Refrigerator	50.1	94.2
Air conditioning	4.1	28.8
Television	71.1	98.2
Video-tape-cd player	22.7	89.8
Radio	81.8	82.5
Telephone	15.0	62.0
Mobile phone	3.8	93.2
Washing machine	11.3	69.9
Mosquito wire net	16.5	57.8
Water supply	Proportion with supply (%)	
	When aged 10–12 years (N = 86 693)	Now (N = 86 594)
Piped supply	19.9	36.3
Underground well	43.3	13.6
Rain water	54.0	23.4
River-canal-stream-lake-pond	7.9	1.2
Bottled water	7.2	48.1
Commercial dispenser	0.3	6.1
Urban-rural location ^a	BMI (N = 85 982)	
	Males	Females
RR		
Underweight	6.6	22.0
Normal	52.9	60.0
At risk	20.8	9.2
Overweight	19.7	8.7
RU		
Underweight	5.3	21.9
Normal	49.6	61.1
At risk	22.7	9.0
Overweight	22.5	8.0
UR		
Underweight	6.5	18.1
Normal	42.5	54.5
At risk	22.7	11.9
Overweight	28.3	15.5

UU

Underweight	6.2	20.1
Normal	42.8	54.6
At risk	21.5	11.0
Overweight	29.5	14.4

^aResidence aged 10–12 years and now: RR, Rural–Rural; RU, Rural–Urban; UR, Urban–Rural; UU, Urban–Urban. BMI: underweight <18.5; normal 18.5–22.9; at risk 23–24.9; overweight 25+.

but surely essential to ensure safety of our respondents. As well, we would be likely to lower the response rate if we included such questions.

One redeeming aspect of this overall health-risk transition study is that additional research that goes beyond the cohort study, designed to fill the gaps, is already included in the agenda. For example, one of the PhDs is on the sexual health transition and another is on health service and income transitions, both important additions. Other ancillary studies are underway on food transitions and dietary diversity, cancer, self-reported health measurement (SF36), the demographic transition and its timing and avian influenza risks.

One weakness of the study at baseline was the great length of the questionnaire which must have lowered response rates somewhat and which created an enormous work load for the Thai team. The length reflected the need for diverse information as well as the need to work across many disciplines. It is worth noting that the cross-disciplinary construct led initially to a 60-page questionnaire and it was very difficult to reduce this and retain confidence of disciplinary experts within the team. Perhaps future studies of this type would be wise to start with fewer disciplines.

Can I get hold of the data?

The data have not yet been made available outside of our large group of collaborators but we have devised a Data Access Agreement that works well among ourselves. This involves a sunset clause, naming of all collaborating personnel, naming of the topic and specification of the variables required. This process could be extended to external collaborators and those interested should contact the Principal Investigators (AS/SS). We also welcome exchange of ideas on other aspects of the study, such as the conceptual background or data management, and proposals to add to the research. The study websites are <http://stoucohort.com/> and <http://nceph.anu.edu.au/>.

Supplementary material

Supplementary data (colour images for figures 1 and 2) are available at *IJE* online.

Acknowledgements

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Conflict of interest: None declared.

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Questionnaire

The Thai Health-Risk Transition: A National Cohort Study

Student Identification Number N N N N N N N N N N

Details about respondent

Citizen Identification Number N N N N N N N N N N

Name.....Family name.....

Address: No.....Moo Ban.....Soi.....Road.....

Tambol/Kwang.....District/Khet.....Province.....

Post code N N N N N

Home Tel. Office Tel.....Mobile.....

e-Mail.....

This page will be
separated and treated
as confidential

Other contact person (If we cannot contact you)

Name.....Family name.....

Address: No.....Moo Ban.....Soi.....Road.....

Tambol/Kwang.....District/Khet.....Province.....

Home Tel. Office Tel.....Mobile.....

Questionnaire Code N N N N N N
(Official use only)



Information

The questionnaire of the Thai Health-Risk Transition Project aims to study the health transition of Thai people in order to understand factors affecting health which will render the healthy public policy recommendation in the future. This study considered the students of Sukhothai Thammathirat Open University as the representatives of the Thai population.

The success of this study depends on co-operation from STOU students in responding to the questionnaire. Participation to the study is voluntary with no influence on academic results at STOU.

All information will remain confidential and will only be used in the research work. None of the information will be disclosed unless permitted by the respondent.

Further information about the project can be obtained or if you have any queries please contact Dr. Sam-ang Seubsman, Thai Health-Risk Transition Office, Room 101 Tri Sorn Building, Sukhothai Thammathirat Open University, Tel/Fax 02 504 7780 or Email tcs@stou.ac.th or visit website: <http://www.stou.ac.th/ANU/>

If you agree to take part in the Thai Health-Risk Transition Project, please sign in the space below.

I agree to participate in the “Thai Health-Risk Transition : A National Cohort Study”

Name.....
(.....)
date/...../.....

Special for Thai Health-Risk Transition Project member

Free!

Within 2 months of returning this questionnaire to STOU, you will be able to access **MyData Base** which will act as your own data base in the internet with free capacity of 20MB for one year. You can create your own website under 5 names and there are also many tools available. You can access by going to <http://www.tcsstou.net> and type in student ID as your Username. As for the Password please type in your birth date which consists of 8 digits (as answer in A1) eg. birth date of March 5, 2512 (B.E.), the Password is 05032512. Please change your Password after first access for confidentiality.

We still have special arrangement for you, please turn to the back cover for information

Please tick (✓) in the **b in front of the selected choice to get to this image ** Please select only one answer except for those that indicate (please tick all that apply) after the questions. For questions that ask for numeric answers, please write the correspondent number in the box **N** one by one by using dark colour pen. (black or blue)

A YOU AND YOUR HOME

A1 In what year were you born? (Please use numbers only)

N N / N N / N N N N

Day month year (B.E.)

(Please complete in numeric form for 8 digits which will be used as a password for MyDataBase at <http://www.tcsstou.net> within 2 months after receiving the questionnaire)

A2 You are:- **b** Male **b** Female

A3 How many brothers do you have in total?

(not include yourself) **N N** persons

A4 How many sisters do you have in total?

(not include yourself) **N N** persons

A5 Where did you come in the order of

births? **N N**

A.6 What is your highest level of education (do not include the your current STOU degree)?

- B** junior high school or equivalent
- B** high school or technical equivalent
- B** post-high-school diploma/certificate
- B** bachelor or higher university degree

A7 Do you **think you** have ethnic **or cultural** links to any of the following groups? (tick all that apply)

- B** Chinese **b** Mon
- B** Central Thai **b** North-eastern Thai
- B** Northern Thai **B** Southern Thai
- B** Other groups

A8 What is your current status?

- b** Single → go to A11
- b** Living with partner → go to A11
- b** Married

A9 What is your current marital status? (tick one only)

- B** Married – first and only marriage
- b** Remarried – second or later marriage
- b** Separated from someone you have been married to (but not divorced)
- b** Divorced
- b** Widowed

A10 What age did you first marry? **N N** year old

What is 'home'? For the next questions, if you:

- have just one home always answer about that home
- are 4 days/month or more at a **permanent** home, answer for that home
- are less than 4 days/month at a permanent home answer for the **working** home

Questionnaire Code **N N N N N N**
(Official used only)

A11 Apart from your permanent family home do you stay at another residence when you are working?

B Yes

b No —————→ **skip to A13**

A12 how often are you at the permanent family home?

N N days/month (average)

A13 In the last 5 years, have you moved your permanent family home?

B Yes **b** No → **go to A15**

A14 Which of the following best describes your last move :

B rural-to-rural

B rural-to-urban

B urban-to-urban

B urban-to-rural

A15 Who is the head of your home?
(choose one answer that fits best)

b I am

b My husband/wife

b My father

b My mother

b My father-in-law

b My mother-in-law

b Relatives/another male

b Relatives/another female



A16 How many people in total live in your home, including yourself? **N N**

A17 How many people aged 15 years or under live in your home? **N N**

If no, please fill 0 in the box **N N** as follow **0 0**

A18 Do any of the following people usually live in your home? (tick all that apply)

B Spouse / partner

B Adult son/daughter (aged 16 years or more)

B Adult brother/sister (aged 16 years or more)

B Parent

B Grandparent

B Other relative/son-in-law/daughter-in-law

B Non-relative

A19 What best describes your home?
(choose one that fits best)

B Detached house

B Semi-detached house

B Shop-front or row-house

B Town house

B Dormitory, flat, apartment,
condominium

B Other

A20 Is your home...

B Owned by you and/or your spouse?

B Hire purchased (mortgaged)?

B Not owned but rent free? (e.g. living
with parents)

B Rented?

B Other?

A21 How much of a problem are the following within 1 km of your home? (Tick ✓ *that fits best in each item*)

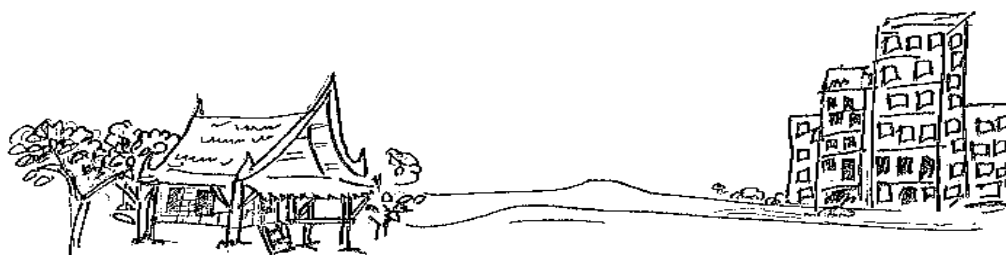
	A big problem	A bit of a problem	Not a problem	Do not know
Air pollution				
Water pollution/waste water				
Noise				
Industrial chemicals				
Agrochemicals				
Pesticides/ herbicides				
Rubbish lying around				
Bad odours				
House break ins				
Poor public transport				
Lack of footpaths				
Lack of recreation areas				
Dogs that may bite				

Below we ask about your home now and as you recall from your childhood when you were **about 10–12 years of age**. This allows us to look at transitions and time effects.

A22 your home now and as you recall from your childhood

Where is your current permanent home located now? **b** Countryside **b** City/Town

Where was your permanent home when you were a child? **b** Countryside **b** City/ Town



Question about your childhood

A23 Which of the following did your home have when you were **10-12 years-old (Grade 4-6)**?

(tick all that apply)

☐ Electricity – local generator

☐ Electricity – outside line

☐ Microwave oven

☐ Refrigerator

☐ Electric fan

☐ Air conditioning

☐ Television

☐ Video / tape/ CD player

☐ Radio

☐ Computer

☐ Telephone

☐ Mobile phone

☐ water heater

☐ Washing machine

☐ Mosquito bed-net

☐ Mosquito wire-net

☐ Do not have the above items



A24 What was the main source of your home drinking water when you were **10-12 years-old (Grade 4-6)**? (whether filtered or not)

☐ Piped supply

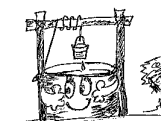
☐ Well or underground water

☐ Rain water

☐ River, canal, stream, pond or lake

☐ Bottled water

☐ Water from other source (e.g. commercial dispenser)



Questions about present time

A25 Which of the following does your home have **now**? (tick all that apply)

☐ Electricity – local generator

☐ Electricity – outside line

☐ Microwave oven

☐ Refrigerator

☐ Electric fan

☐ Air conditioning

☐ Television

☐ Video / tape/ CD player

☐ Radio

☐ Computer

☐ Telephone

☐ Mobile phone

☐ water heater

☐ Washing machine

☐ Mosquito bed-net

☐ Mosquito wire-net

☐ Do not have the above items



A26 What is the main source of your home **drinking water now**? (whether filtered or not)

☐ Piped supply

☐ Well or underground water

☐ Rain water

☐ River, canal, stream, pond or lake

☐ Bottled water

☐ Water from commercial dispenser

B INCOME AND WORK

B1 What is your average personal monthly income?

B less than 3,000 Baht	B 3,001-7,000 Baht	B 7,001-10,000 Baht
B 10,001-20,000 Baht	B 20,001-30,000 Baht	B over 30,000 Baht

B2 Do you work for income?

- B** Yes → **go to B4** **b** No

B3 If not working for income at present are you best described as:- (*tick one option that fits best*)

B Homemaker ?	B Seeking work for first time?
B Unpaid family worker (not homemaker)	B Unemployed ?
B Wholly Retired? (do not work for income)	B Student ? (do not work)
B Unable to work owing to permanent sickness/ disability ?	B Other?



For those who do not work for income after answered B3 please go to C1

B4 Which category best fits your main job? (*Please tick one only*)

b Government/state enterprise/Institution employee	
b Private employee	
b Employer _____	go to B 7
b Self-employed (without employees, not agriculture) _____	go to B 7
b Own farm/ garden _____	go to B 7
b Other _____	go to B 7

B5 If employed as Government/state enterprise/Institution/Private employee for your main income-earning job, are you....

- B** Permanently employed
- b** On a fixed length contract (e.g. 1 year contract or more)
- b** Casually employed
- b** Other

B6 How many hours do you usually work each week in all paid jobs? **N N** total hours

B7 Do any paid hours involve shift work at night or weekends?

B Yes

b No

B8 How secure do you feel about your job or career future in your current **occupation**?

b Not at all secure

b Moderately secure

b Secure

b Extremely secure

B9 How often do you extend your workday to continue after 6pm? (paid or unpaid)

b 5-7 days/week

b 2-4 days/week

b 1-4 times/month

b Less often

b Never

B10 In total, **on average** how long per day do you spend traveling from home to work (one-way)?

B Less than 30 minutes

b 30 minutes – 1 hour

b 1-2 hours

b 2-3 hours

b More than 3 hours

b Do not have to travel

B11 In your main income-earning job, how would you describe yourself? (*you may tick more than one*)

B professional (eg accountant, doctor)

b skilled worker (eg carpenter, dressmaker)

b senior manager

b middle manager

b office assistant

b manual worker

b other

B12 Your work situation. (Please tick ✓ to fit best for each question)

Working situation	Often	Sometimes	Rarely	Never
I have a good deal of say in decisions about work				
My working time can be flexible				
I have to do the same thing over and over again on a regular basis				
I have enough time to do everything				
I have to work very fast				

B13 During the last 12 months, how often have you experienced at work each of the following? (Please tick ✓ to fit best for each question)

Environment	Often	Sometimes	Rarely	Never	Don't know
Vibrations from hand tools or machinery					
Noise so loud that you had to raise your voice to talk to people					
High temperatures which make you uncomfortable					
Temperatures too low					
Vapours, fumes, dust, or dangerous substances (such as chemicals, infectious materials)					
Handling or touching dangerous products or substances					

C YOUR HEALTH, INJURIES AND HEALTH SERVICE USE

C1 What is your weight? **N N N** Kilograms

C2 What is your height without shoes? **N N N** Cm

C3 Which best describes your size or weight (recalled by relatives) when you were born?

B Small or under weight	b Normal
b Large or over weight	b Do not know —————→ skip to C5

C4 My birth-weight was (if known): **N N N N** grams

C5 Recalled by relatives, when you were an infant were you breast fed ?

b Yes	b No —————→ skip to C7
	b Do not know —————→ skip to C7

C6 If Yes, how long were you breast fed? **N N** months

C7 Which statement best describes your current eyesight?

b	I do not need glasses
b	I need glasses/contact lenses since childhood (<13 years old)
b	I need glasses/contact lenses since a teenager (13-19 years old)
b	I need glasses/contact lenses since adulthood (20 years old or more)



C8 Do you currently have any sight problems not correctable by glasses/contact lenses? (eg cataract etc.)

☐ Yes

☐ No

C9 Which statement best describes your current hearing (without a hearing aid)?

☐ Good

☐ Some trouble, since childhood (<13 years old)

☐ Some trouble, since teenage or adult (13 years or more)

☐ Deaf since childhood (<13 yrs old)

☐ Deaf since teenage or adult (13 years or more)

C10 Adults can have up to 32 natural teeth. How many of your own teeth do you have?

☐ None

☐ 1-5

☐ 6-19

☐ 20 or more



C11 Do your teeth or dentures currently cause you...*(please tick all that apply)*

☐ discomfort speaking?

☐ discomfort swallowing?

☐ discomfort chewing?

☐ Loss of confidence when engaging in social interaction

☐ Pain

☐ None of these

C12 In the past 4 weeks, about how often... (Please tick ✓ to fit best for each question)

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
Did you feel nervous?					
Did you feel restless or fidgety?					
Did you feel that everything was an effort?					



C13 The next questions ask about some health conditions whether you ever been told by a doctor that you have this condition. *(please tick all that apply)*

☐ Diabetes (needing insulin)	☐ Liver disease (not cancer)
☐ Diabetes (do not need insulin)	☐ Kidney disease
☐ High cholesterol/high blood lipids	☐ Depression / anxiety
☐ High blood pressure	☐ Arthritis
☐ Ischemic (coronary) heart disease	☐ Pneumonia
☐ Cerebrovascular disease (stroke)	☐ Chronic bronchitis/lung disease
☐ Liver cancer	☐ Asthma
☐ Lung cancer	☐ Malaria
☐ Cancer of the digestive system	☐ Dengue fever
☐ Breast cancer	☐ Tuberculosis
☐ Other cancers	☐ Other chronic infection
☐ Goiter / Thyroid abnormality	☐ Other diseases not mentioned above
☐ Epilepsy	☐ Never been to the doctor



C14 Overall how would you rate your health during the past 4 weeks?

☐ Excellent	☐ Very good	☐ Good
☐ Fair	☐ Poor	☐ Very poor

C15 During the past 4 weeks, how much did physical health problems limit your usual physical activities (such as walking or climbing stairs)?

☐ Not at all	☐ Very little	☐ Somewhat
☐ Quite a lot	☐ Could not do physical activities	

C16 During the past 4 weeks, how much difficulty did you have doing your daily work, both at home and away from home, because of your physical pain?

☐ None at all	☐ A little bit	☐ Some
☐ Quite a lot	☐ Could not do daily work	



C17 How much bodily pain have you had during the past 4 weeks?

☐ None	☐ Very mild	☐ Mild
☐ Moderate	☐ Severe	☐ Very severe

C18 During the past 4 weeks, how much energy did you have?

B Very much	B Quite a lot	B Some
B A little	B None	

C19 During the past 4 weeks, how much did your physical health or emotional health problems limit your usual social activities with family or friends?

B Not at all	B Very little	B Somewhat
B Quite a lot	B Could not do social activities	

C20 During the past 4 weeks, how much have you been bothered by emotional problems (such as feeling anxious, depressed or irritable)?

B Not at all	B Slightly	B Moderately
B Quite a lot	B Extremely	

C21 During the past 4 weeks, how much did personal or emotional problems keep you from doing your usual work, school or other daily activities?

B Not at all	B Very little	B Somewhat
B Quite a lot	B Could not do daily activities	

C22 In the last 12 months how many **serious** injuries have you had that were enough to interfere with daily activities and/or required medical treatment?

- B** None —————→ **please go to C28**
- B** once **b** twice **b** 3 times **b** 4 times or more



Please answer C23-C27 for your most serious injury during the last 12 months

C23 Where were you when you were **seriously** injured?

B Home	B Road
B Sports facility	B Workplace (<i>agricultural</i>)
B Workplace (<i>non-agricultural</i>)	B Other

C24 Was this **serious** injury related to road traffic?

- B** Yes **B** No —————→ **please go to C26**

C25 If a traffic injury, what were the circumstances?

C25A What was your role?

B Driver **B** Passenger **B** Pedestrian → **skip to C25C**

C25B What type of vehicle were you driving or a passenger in?

B Bicycle **B** Motor-bike **B** Bus, van, tour coach
B Car/pickup **B** other eg. train, boat, airplane

C25C Who was the other party **in this serious accident**?

B Bicycle **B** Motor-bike **B** Bus, van, tour coach
B Car/pickup **B** other eg. train, boat, airplane
B other object that is not vehicle eg. tree, other obstruction

C26 If not a traffic injury, how were you seriously injured? (*please tick one box that fits best*)

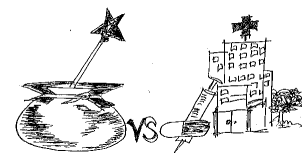
b Assault (punch, push or kick)	b Gun shot
b Fall (not pushed)	b Stab/Cut
b Other blunt force	b Fire, heat
b Drowning	b Poisoning
b Bite or sting (animal, insect)	b Other

C27 Was the serious injury? (*please tick one box that fits best*)

b Accidental **b** Non-accidental (involving another person)
b Non-accidental (no other person involved)

C28 In the past 12 months, have you personally used any of the following health services?
(please tick all that apply)

B Government health centre	B Community Hospital
B Government clinic	B Provincial/other government hospital
B Private clinic	B Private hospital
B Traditional healer (<i>Thai/ Chinese/other</i>)	B Other
B None — if 'none' go to Question C30	



C29 Which of the following did you use in the past 12 months to cover costs of your medical treatment? (*please tick all that apply*)

B Non-government employer scheme	B Civil servant/state enterprise benefit scheme
B Private health insurance	B 30 Baht scheme
B Self-payment	B Other

C30 In the past 12 months was there any occasion when you consider you should have used health services for an illness or injury, but you did not use the service?

B Yes

b No —————→ **if 'No' please go to C32**

C31 If yes, why did you not use the health services? *(please tick all that apply).*

B Too expensive

B Too difficult to travel to the service

B Had to wait too long

B Not satisfied with services

B Scared of going

B Don't like health provider (Doctor, nurse, other staff)

B Could not get time off work/too busy at work

B Could not get away from family commitments

B Other



C32 Medication in the past 12 months:-
(Please tick ✓ to fit best for each question)

	Yes	No
Have you taken (eaten, injected, rubbed on etc.) medication prescribed by a <u>medical doctor</u> or other health personnel?		
Have you purchased any medication that did not require a doctor's prescription??		
Have you used traditional and/or herbal medicines		

D SOCIAL NETWORKS AND WELL-BEING

D1 How frequently you do each of the following activities? *(Please tick ✓ to fit best for each question)*

	Everyday	Nearly/ every week	1-2 times/month	Very few	Never
Spend time with <u>parents</u> or other relatives					
Spend time socially with <u>neighbors</u>					
Spend time socially with colleagues from work or your profession					
Spend time socially with other friends (old friends etc.)					
Spend time with people at your temple, mosque or other <u>place of worship</u>					
Spend time socially with people at recreational clubs or voluntary or service organization					
Participate in political parties, trade unions, environmental groups					

D2 Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?

- B** Most people can be trusted **b** You must be wary of people all the time

D3 How would you rate the support you are getting from the following:
(Please tick ✓ to fit best for each question)

	Very little support	A little support	Quite a bit of support	A lot of support	Not relevant
Your family?					
neighbours/local people?					
Local government officials?					
Religious groups?					
Friends?					
employer/ boss?					
others in the workplace?					

D4 What is your religion?

- B** Buddhism **B** Islam **b** Christianity **b** Hinduism **b** Other **b** None

D5 In your life:- (for each question, tick the box that fits best on the zero-to-ten scale)



	Not at all ← → Very much										
	0	1	2	3	4	5	6	7	8	9	10
how important is religion to calm your mind when facing problems?											
how important are spiritual practices (eg sado clo or praying)?											
how important is karma?											

D6 Thinking about your own life and personal circumstances, how satisfied are you with...
(tick box on zero-to-ten scale that fits best for each question)

	Completely Dissatisfied					Completely Satisfied					
	0	1	2	3	4	5	6	7	8	9	10
...your standard of living?											
...your health?											
...what you achieve in life?											
...your personal relationships?											
...how safe you feel?											
...feeling part of your community?											
...your future security?											
...the neighbourhood where you live?											
...your religion or spirituality?											
...your life as a whole?											

D7 Have you had to go without things you really needed in the last 12 months because you were short of money?

B Yes, often **b** Yes, sometimes **b** No, never

E FOOD AND PHYSICAL ACTIVITY



E1 How often, on average, do you eat each of the following foodstuffs?
(Please tick ✓ to fit best for each question)

	Never or less than once a month	1-3 times/month	1-2 times/week	3 - 6 times/week	Once a day or more
Food/dessert with coconut milk					
Deep fried food					
Fermented food...fish/crab					
Roasted/smoked food eg. Thai sausage/roasted chicken					
Uncooked meat or shrimp					
Fermented fruit/vegetable					
Instant food					
Canned food					
Soft drink					
Milk eg. Fresh, carton or powder milk					
Soybean products eg. soya milk, tofu					
Food supplements, vitamins, minerals					

E2 Typically, how often do you eat in (or eat food from) each of the following?

(Please tick ✓ to fit best for each question)

Source/location of food purchases	Never / Less than once a month	1-2 times /month	Once a week or more	Everyday / most days
Restaurant where you pay more than 200 Baht/ person				
Food shop where you pay less than 100 Baht/ person				
Western-style Fast Food (e.g. burger, pizza)				
Work Canteen				
Street vendor / Market stall				
Home delivery (e.g. pizza)				
Food prepared at home				

E3 How important is each of the following in influencing your choice of foods?

(Please tick ✓ to fit best for each question)

	Very important	Important	Of minor importance	Unimportant
Cost – foods I can afford				
Health – try to provide healthy diet				
Taste – foods I like eating				
Convenience – ready to eat				
Limited cooking or storage facility				
Ability to carry and transport foods				
Culture – traditional foods				
Habit – what I usually have to eat				
Religion				
Food safety concerns				

E4 How many serves of vegetables do you usually eat each day?
(one serve = ½ cup cooked or 1 cup uncooked)

N N no. of serves

E5 How many serves of fruit do you usually eat each day?
(one serve, equivalent to 1 cup of diced pieces)

N N no. of serves

E6 During a typical week (7-day period), how many times on average do you do the following kinds of exercise? (Enter '0' if you do not do any of that type of exercise)

	Times per Week
Strenuous exercise (heart beats rapidly) for more than 20 minutes <i>e.g. heavy lifting, digging, aerobics or fast bicycling, running, soccer, trakraw</i>	N N
Moderate exercise (not exhausting but breathe harder than normal) for more than 20 minutes <i>e.g. carrying light loads, cycling at a regular pace,</i>	N N
Mild exercise (minimal effort) for more than 20 minutes <i>e.g. yoga, Tai-Chi, bowling</i>	N N
Walking (non-stop) for at least 10 minutes <i>e.g. at work, at home, exercise</i>	N N

E7 How often do you do household cleaning or gardening work?

- b** Seldom or Never **B** 1-3 times/ month
b Once or twice/ week **b** 3-4 times/ week
b Most days



E8 How many hours per day in total do you usually spend:

activities	duration
Sleeping? (if you regularly sleep during the day include this also)	N N hours/day
Watching TV and/or playing computer games	N N hours/day
Sitting for <u>any</u> purpose (<i>eg reading, resting, working, thinking</i>)?	N N hours/day



F

TOBACCO, ALCOHOL AND TRANSPORT

F1 F1 Have you ever smoked?

- B** Yes **b** No → If 'no' please go to question F5

F2 At what age did you **start** smoking N N years

F3 If you have **quit** smoking, at what age did you stop? N N years **b** still smoking

F4 How many cigarettes do you smoke per day now (if current smoker), or did you
 smoke per day (if former smoker)? N N number per day

F5 Are you exposed on most days to smoke coming from other people who are smoking?
(Tick all that apply).

b Yes, at home

b Yes, in a recreation place

b Yes, in the workplace

b Yes, at public transport station eg. train/bus station

b Yes, other places

b No

F6 Have you ever drunk alcohol?

b Occasional social drinker

b No, never —→ **Please go to question F11**

b Current regular drinker

b Used to drink before, now **stopped**

F7 At what age did you start drinking alcohol?

N N years

F8 If you have **quit** drinking, at what age did you stop?

N N years **b** still drinking

F9 How many glasses of alcohol do/did you have **in one sitting** when you are/were drinking?

B less than 2 glasses

b 2-3 glasses

b 4-5 glasses

b 6 glasses or more

F10 During the last 12 months have you driven a motor vehicle after consuming 3 or more glasses of alcohol?

B Yes

b No

b Do not normally drive

F11 Which of the following do you, or any member of your household, own?
(Please tick all that apply)

B Bicycle

b Motorcycle

b Car/pick-up/van

B Truck

B Boat

B No vehicle



F12 How often do you use a safety belt when driving or sitting in a car?
(Please answer for both front and back seat)

Safety belt	Always wear safety belt	Sometimes wear safety belt	Never choose to wear safety belt	Vehicle doesn't have safety belt
Front Seat				
Back Seat				



F13 How often do you wear a helmet when you travel on or ride a motorbike?

B Regularly

b Sometimes

B Rarely or never

b I do not ride motorbikes

F14 How often do you ride in the back of an open truck or pick-up?

B Regularly

b Sometimes

b Rarely/ Never



YOUR FAMILY

G1 about your parents

Mother	Father
What is the highest grade of education completed by your mother?	What is the highest grade of education completed by your father?
B No formal education	B No formal education
b Primary level	B Primary level
B Secondary level	B Secondary level
B Tertiary level	B Tertiary level
B Do not know	B Do not know
Is your mother still alive?	Is your father still alive?
No At what age did she die? N N years	b No At what age did he die? N N years
B Yes What is her age? N N years	b Yes What is his age? N N years
↓ If both of them are still alive → skip to G3	

G2 What did your mother and/or father die from? (you may tick ☒ more than one cause; leave column blank for the irrelevant box)

	Mother	Father
Heart disease	b	b
High blood pressure	b	b
Stroke	b	b
Cancer	b	b
Tuberculosis	b	b
Pneumonia	b	b
Other infection	b	b

	Mother	Father
Diabetes	b	b
Kidney disease	b	b
Injury	b	b
Child birth	b	b
Old age	b	b
Other	b	b
Do not know	b	b

G3 Do you have children?

B Yes **b** No

If 'no' skip to G18 The next section is for those who have had children

G4 How many daughters do you have now?

N N

How many sons do you have now?

N N

G5 Would you like to have more children?

B Yes

B No



G6 Have you ever had a child who was born alive but later died?

B₁ Yes

B₂ No

G7 How old were you when your first child was born?

N N years

G8 Is your youngest child:

B Female

B Male

G9 How old is your youngest child now?

N N years and **N N** months

(ex. 3 years and 11 months) only child is considered as youngest child too.

G10 What is the size of your youngest child now?

Weight **N N . N** Kgs **b** Do not know

(eg 10.5 kgs)

Height **N N N** Cms **b** do not know

G11 What was the weight at birth of your youngest

child? **N N N N** grams

b do not know

G12 Was this youngest child breastfed after birth?

B Yes

B No → skip to G14

G13 If Yes, how many months?

N N months

G14 Have any of your children ever been diagnosed with asthma?

B Yes

B No → skip to G16

G15 If Yes, which one(s)? (Please tick all that apply)

B 1st child

B 3rd child

B 2nd child

B 4th or later child

G16 Have any of your children ever had allergic sneezing, coughing, mucus without having a cold?

B Yes

B No → skip to G18

G17 If Yes, which one(s)? (Please tick all that apply)

B 1st child

B 3rd child

B 2nd child

B 4th or later child

The last question is about your pets

G18 Do you have the following pet animals at home? (Please tick all that apply)

B Dog

b Cat

B Bird

b Other

B Do not have pet animals





โครงการวิจัยสุขภาพ มหาวิทยาลัยสุโขทัยธรรมาธิราช ขอขอบคุณทุกท่านสำหรับความร่วมมือครั้งนี้



Universal codes:

- 7 = "Multiple response". It is assigned to data item where **program** detected that there are more than one checkbox being checked for any multiple choice questions.
- 9 = "Missing value". It is assigned to data item where **program** detected that the data image is blank.



address1

MEMBER CODE TCSID

0	1	5	7	7

tcsid

Dear STOU cohort member,

Thank you for participating in the Thai Health-Risk Transition study. The information you provided 3 years ago shows that there are many factors affecting our health as we reported back to you last year when we posted the 'Love Your Health' booklet.

We are now sending you a *first follow-up questionnaire* which will explore the changes you have experienced in the last 3 years. This new information will enrich our understanding of health and well-being in Thailand. With these insights we can help develop national responses to help Thais live healthy and fulfilling lives.

It is a privilege to work with you on this health project. We hope you find time to complete the questions attached and return by post in the stamped envelope provided.

We understand that your participation is voluntary and that you may withdraw from the study at any time. We certify that all your information will remain confidential. Your name and other details will never be released, and will only be used to make further contact with you. For any analyses and reports all identifying information will be removed from the data.

If you are the person to whom this document was addressed above, and you are willing to continue participating, please sign below.

sign

Your Signature (0 = no text, 1 = text) Date / /

Mr/Miss/Mrs

If you changed your address or contact details please fill in the information on the next page and return it with the questionnaire in the envelope provided.

For any assistance regarding this study please call our help line toll free 02-5047780 (working hours). Thank-you to all our members.

Associate Professor Sam-ang Seubsman
Principal Investigator, Thai Health-Risk Transition Study
Sukhothai Thammathirat Open University, Nonthaburi

**This page will be
separated and treated
as confidential**

It is important for our study that we can maintain contact with you. If your name, address or other details have changed from those shown on the front of the envelope, please place a cross in one of the following boxes. Please use a blue or black pen

add1 (-9 = missing)

☐ Have not changed any personal information

Please go to the instructions
at the top of the next page

☐ There has been a change to my personal information as follows

**add1n1
(0, 1)**

☐ Name

**add1n2
(0, 1)**

☐ Address

☐ Telephone number

**add1n3
(0, 1)**

0 = No response

1 = With response

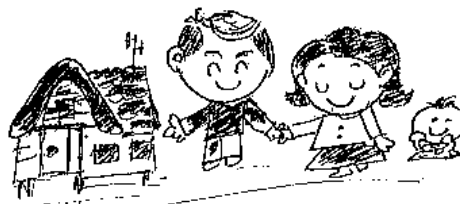
Please give details below

add2an1
First Name..... Family Name.....
Address: No. **add2an2** Moo Ban. **add2an3** Soi. **add2an4** Road. **add2an5**
Tambol/Kwang. **add2an6** District/Khet. **add2an7** Province. **add2an8**
Postcode **add2an9**
Home Tel. **add2an10** Office Tel. **add2an11** Mobile. **add2an12**
Email. **add2an13**

(0 = no text, 1 = text)

Other contact person (if we cannot contact you)

add2bn1
First Name..... Family Name.....
Address: No. **add2bn2** Moo Ban. **add2bn3** Soi. **add2bn4** Road. **add2bn5**
Tambol/Kwang. **add2bn6** District/Khet. **add2bn7** Province. **add2bn8**
Postcode **add2bn9**
Home Tel. **add2bn10** Office Tel. **add2bn11** Mobile. **add2bn12**



Please keep a record of your member code (TCSID) from the front of the envelope to use as a reference in any future communication with the Thai Health Risk Transition Study

This page will be
separated and treated
as confidential

Instructions: Please use a blue or black pen to put a cross (X) in the ☐ in front of the selected choice to get to this image . Select only **one answer** except when instructed that **more than one answer can be given**. For questions that ask for numeric answers, write number(s) **clearly** in the box(es) placing only one number in each box. eg

A General Information about you, work, and home

A1 When were you born? (according to Citizen ID card; please use numbers only)

a1 / /
Day Month Year (B.E.)

Example / /

A2 Where is your current residence located?

a2 ☒ Countryside ☒ City/Town

A3 How many people live in your home, including yourself

a3 People (if you live alone please put)

A4 What is your current work status?

(you can choose more than one option)

- a4n1** ☐ Doing paid work
a4n2 ☐ Self employed
a4n3 ☐ Help family business but no wage
a4n4 ☐ Doing unpaid work
a4n5 ☐ Look after home/homemaker
a4n6 ☐ Student
a4n7 ☐ Retired (do not work for income)
a4n8 ☐ Seeking work for the first time
a4n9 ☐ Unemployed
a4n10 ☐ Cannot work due to temporary sickness/disability
a4n11 ☐ Cannot work due to permanent sickness/disability
a4n12 ☐ Other

A5 How many hours per week do you work in all paid jobs?

a5 total hours (If not working for income put)

A6 What is your personal average monthly income (Baht)

- a6** ☒ Up to 3000
☒ 3,001–7,000
☒ 7,001–10,000
☒ 10,001–20,000
☒ 20,001–30,000
☒ 30,001–50,000
☒ 50,001–70,000
☒ 70,001–100,000
☒ Over 100,000

A7 What is your household's average monthly income (Baht)

- a7** ☒ Up to 3000
☒ 3,001–7,000
☒ 7,001–10,000
☒ 10,001–20,000
☒ 20,001–30,000
☒ 30,001–50,000
☒ 50,001–70,000
☒ 70,001–100,000
☒ Over 100,000

A8 What is your weight now? kgs

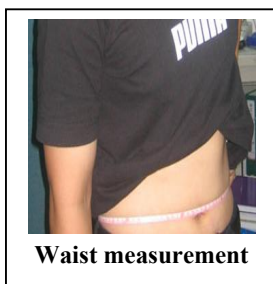
Example

A9 What is your height (no shoes)? cms

-9 = missing at variables; A1, A2, A3, A5, A6, A7, A8, A9
-7 = checked more than one box at variables; A6, A7



Use enclosed tape measure and instructions on use for the next questions



Waist measurement



Hip measurement

If you are pregnant please go to question A12

A10 What is your waist measurement? cms

a10

A11 What is your hip measurement? cms

a11

A12 What is your current marital status? (choose only one answer)

a12

☐ 1

First marriage

☐ 2

Remarried

☐ 3

Separated from someone you have been married to (but not divorced)

☐ 4

Divorced

☐ 5

Widowed

☐ 6

Never married

Skip to question A14

A13 If not currently married, do you have a partner? (choose only one answer)

a13

☐ 1

Have a partner and live together

☐ 2

Have a partner but do not live together

☐ 3

Do not have a partner

A14 How frequently do you spend time doing each of the following activities? (cross box that fits best)

Activities	every day	every week	1-2 times a month	rarely	never
Spend time socially with colleagues from work/your profession	1	2	3	4	5
Spend time socially with friends not connected to work	1	2	3	4	5
Spend time socially with neighbours	1	2	3	4	5
Spend time with parents/other relatives	1	2	3	4	5

A15 Do you regularly care for a sick or disabled family member

a15

☐ 1

No

☐ 2

Yes, part-time

☐ 3

Yes, full-time

A16 In the past 4 weeks, have you had pain in your lower back?

(in the area shown on the diagram)

a16

☐ 1

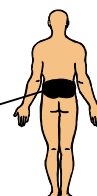
Yes

☐ 2

No

Go to B1

Lower back



A17 If yes, was this pain bad enough to limit your usual activities or change your daily routine for more than one day?

a17

☐ 1

Yes

☐ 2

No

-9 = missing all variables on this page

-7 = checked more than one box at variables; A12 – A17

B

Your general health over the past four weeks

B1 Overall how would you rate your health during the past 4 weeks?

- b1** ☒ 1 Excellent ☒ 2 Very good ☒ 3 Good
☒ 4 Fair ☒ 5 Poor ☒ 6 Very poor

B2 During the past 4 weeks, how much did physical health problems limit your usual physical activities (such as walking or climbing stairs)?

- b2** ☒ 1 Not at all ☒ 2 Very little ☒ 3 Some
☒ 4 Quite a lot ☒ 5 Could not do physical activities

B3 During the past 4 weeks, how much difficulty did you have doing your daily work, both at home and away from home, because of your physical health?

- b3** ☒ 1 None at all ☒ 2 A little bit ☒ 3 Some
☒ 4 Quite a lot ☒ 5 Could not do daily work

B4 How much bodily pain have you had during the past 4 weeks?

- b4** ☒ 1 None ☒ 2 Very mild ☒ 3 Mild
☒ 4 Moderate ☒ 5 Severe ☒ 6 Very severe



B5 During the past 4 weeks, how much energy did you have?

- b5** ☒ 1 Very much ☒ 2 Quite a lot ☒ 3 Some
☒ 4 A little ☒ 5 None

B6 During the past 4 weeks, how much did your physical health or emotional problems limit your usual social activities with family or friends?

- b6** ☒ 1 Not at all ☒ 2 Very little ☒ 3 Somewhat
☒ 4 Quite a lot ☒ 5 Could not do social activities

B7 During the past 4 weeks, how much have you been bothered by emotional problems (such as feeling anxious, depressed or irritable)?

- b7** ☒ 1 Not at all ☒ 2 Slightly ☒ 3 Moderately
☒ 4 Quite a lot ☒ 5 Extremely

B8 During the past 4 weeks, how much did personal or emotional problems keep you from doing your usual work, school or other daily activities?

- b8** ☒ 1 Not at all ☒ 2 Very little ☒ 3 Somewhat
☒ 4 Quite a lot ☒ 5 Could not do daily activities

-9 = missing all variables on this page

-7 = checked more than one box all variables on this page



C1 In the past 4 weeks, how much of the time did you feel...

(Please cross box that fits best for each question)



Feeling	all of the time	most of the time	some of the time	a little of the time	none of the time
...so sad nothing could cheer you up? c1n1	1	2	3	4	5
...nervous? c1n2	1	2	3	4	5
...restless or fidgety? c1n3	1	2	3	4	5
...hopeless c1n4	1	2	3	4	5
...everything was an effort? c1n5	1	2	3	4	5
...worthless? c1n6	1	2	3	4	5
...happy? c1n7	1	2	3	4	5

C2 Thinking about your own life and personal circumstances, how satisfied are you with...

(Cross box on 0-10 scale that fits best for each question)

Feelings for your life and circumstances	Completely Dissatisfied ←————→ Completely Satisfied										
	0	1	2	3	4	5	6	7	8	9	10
...your standard of living? c2n1	0	1	2	3	4	5	6	7	8	9	10
...how safe you feel c2n2	0	1	2	3	4	5	6	7	8	9	10
...feeling part of your community c2n3	0	1	2	3	4	5	6	7	8	9	10
...your life as a whole c2n4	0	1	2	3	4	5	6	7	8	9	10

C3 Have you had to go without things you really needed in the last 12 months because you were short of money?

c3 ☒ Yes, often ☒ Yes, sometimes ☒ No, never

C4 Generally speaking, would you say that most people can be trusted or that you can't be too careful in dealing with people?

c4 ☒ most people can be trusted ☒ You must be wary of people at all times

C5 Compared to other Thais your age how modern are you?

Modernity	Not modern ←————→ Very modern										
	0	1	2	3	4	5	6	7	8	9	10
Your level of modernity c5	0	1	2	3	4	5	6	7	8	9	10

-9 = missing all variables on this page

-7 = checked more than one box all variables on this page

C6 What are your views/feelings on the following statements? (cross the box that corresponds with your feelings)

Feelings	never	a little	a lot	very much
I am contented with life c6n1	1	2	3	4
I feel relaxed c6n2	1	2	3	4
I feel bored and discouraged with my daily life c6n3	1	2	3	4
I feel disappointed in myself c6n4	1	2	3	4
I feel life is full of miseries c6n5	1	2	3	4
I can face and accept problems which are difficult to solve c6n6	1	2	3	4
I am confident I can control my emotions in case of crisis c6n7	1	2	3	4
I feel confident in facing life's crises c6n8	1	2	3	4
I feel sympathetic towards others' suffering c6n9	1	2	3	4
I feel happy in helping out others when they have problems c6n10	1	2	3	4
I help others when I have the chance c6n11	1	2	3	4
I have self esteem c6n12	1	2	3	4
I feel secure when I stay with my family c6n13	1	2	3	4
If I become seriously ill I trust my family will take good care of me c6n14	1	2	3	4
My family members love and care for each other c6n15	1	2	3	4

D Your food and physical activity



D1 How often, on average, do you eat each of the following food stuffs? (Cross box that fits best for each question)

Type of food	Never or < 1/mth	1-3/mth	1-2/wk	3-6/wk	Daily or more
Food/dessert with coconut milk d1n1	1	2	3	4	5
Deep fried food d1n2	1	2	3	4	5
Instant noodles d1n3	1	2	3	4	5
Fermented food eg. Crab, fish d1n4	1	2	3	4	5
Soft drink d1n5	1	2	3	4	5
Milk – fresh, carton or powder d1n6	1	2	3	4	5
Food supplements, vitamins d1n7	1	2	3	4	5
Fast food (Western style/farang) eg. hamburger, pizza d1n8	1	2	3	4	5
Western bakery products eg.cake,cookies d1n9	1	2	3	4	5

D2 How many serves of vegetables do you usually eat each day? d2 no. of serves per day
 Eg. If you eat 3 serves put in the numbers like this 03 (one serve = ½ cup cooked or 1 cup uncooked)

D3 How many serves of fruit do you usually eat each day? d3 no. of serves per day
 Eg. If you eat 5 serves please put the numbers in like this 05 (one serve, equivalent to 1 cup of diced pieces)

-9 = missing all variables on this page

-7 = checked more than one box all variables on this page except d2, d3

D4 In what way is rice important for you?

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly disagree
I never feel full unless I have eaten rice d4n1	1	2	3	4	5
No meal is complete without rice d4n2	1	2	3	4	5
Rice is the perfect food d4n3	1	2	3	4	5

D5 During a typical week (7-day period) how many times on average do you do each of these physical activities? (if your answer is 0 times per week mark boxes if it is 3 times per week mark boxes)

Walking continuously, for at least 10 minutes (for work, recreation or exercise or to get to or from places) d5n1		Times per week
Vigorous physical activities for more than 20 minutes (that made you breathe harder or puff and pant) d5n2		Times per week
Moderate physical activities for more than 20 minutes (like social tennis, golf, gentle swimming or work around the house or other work) d5n3		Times per week

D6 How often do you do household cleaning or gardening work?

- d6** ☐ 1 Seldom or never ☐ 2 1-3 times/month ☐ 3 Once or twice/week
☐ 4 3-4 times/week ☐ 5 Most days



D7 How many hours per day (ie. per 24 hours) do you usually spend on the following activities?

Activities	Duration
Standing for any purpose at all (eg. for work, while socializing etc.) d7n1	hours/days
Sleeping (if you regularly sleep during the day include this also) d7n2	hours/days
Watching TV and/or playing computer games? d7n3	hours/days
Sitting for any purpose? (eg. reading, resting, writing, thinking, TV, or computer) d7n4	hours/days

-9 = missing all variables on this page

-7 = checked more than one box all variables on this page except d5n1 – d5n3, d7n1 – d7n4



About the Weather

E1 How often did the hot period this year interfere with the following activities?

Activity	Never	1-3 times per month	1-6 times per week	Everyday	Not Applicable- Use Air conditioning
Sleeping e1n1	1	2	3	4	5
Housework e1n2	1	2	3	4	5
Daily travel e1n3	1	2	3	4	5
Work e1n4	1	2	3	4	5
Exercise e1n5	1	2	3	4	5



Your injuries

-9 = missing all variables on this page

-7 = checked more than one box all variables on this page



Your injuries – traffic related

F1 In the last 12 months how many times did you get injured in a traffic crash

- f1**
- | | | | |
|----------------------------|-------|----------------------------|--------------|
| ☐ 0 | Never | → | ..go to F7 |
| ☐ 1 | One | ☐ 3 | Three |
| ☐ 2 | Two | ☐ 4 | Four or more |

F2 When you experienced your most serious traffic related injury did you receive medical care?

- f2**
- | | | | |
|----------------------------|-----|----------------------------|----|
| ☐ 1 | Yes | ☐ 2 | No |
|----------------------------|-----|----------------------------|----|

F3 Did this injury limit your normal activities for one day or more?

- f3**
- | | | | |
|----------------------------|-----|----------------------------|----|
| ☐ 1 | Yes | ☐ 2 | No |
|----------------------------|-----|----------------------------|----|

F4 When this injury occurred what was your role?

- f4**
- | | | | |
|----------------------------|------------|----------------------------|------------|
| ☐ 1 | Driver | ☐ 2 | Passenger |
| ☐ 3 | Pedestrian | → | ..go to F6 |

F5 Type of vehicle you were in as driver or passenger?

- f5**
- | | | | |
|----------------------------|--------------------------------|----------------------------|-----------|
| ☐ 1 | Bicycle | ☐ 2 | Motorbike |
| ☐ 3 | Bus, van tour coach | | |
| ☐ 4 | Car/pick-up | | |
| ☐ 5 | Other (eg. Train, plane, boat) | | |

F6 What was the other party in the collision causing the traffic related injury?

- f6**
- | | |
|----------------------------|---|
| ☐ 1 | Bicycle |
| ☐ 2 | Motorbike |
| ☐ 3 | Bus, van, tour coach |
| ☐ 4 | Car/pick-up |
| ☐ 5 | Other vehicle (eg. train, boat) |
| ☐ 6 | Pedestrian |
| ☐ 7 | Animal (eg. Dog) |
| ☐ 8 | Other object not vehicle (eg. tree, road surface, wall) |

Your injuries – non-traffic related

F7 In the last 12 months how many times did you have a NON-TRAFFIC injury?

- f7**
- | | | | |
|----------------------------|-------|----------------------------|--------------|
| ☐ 0 | Never | → | ..go to G1 |
| ☐ 1 | One | ☐ 3 | Three |
| ☐ 2 | Two | ☐ 4 | Four or more |

F8 When you experienced your most serious non-traffic related injury did you receive medical care?

- f8**
- | | | | |
|----------------------------|-----|----------------------------|----|
| ☐ 1 | Yes | ☐ 2 | No |
|----------------------------|-----|----------------------------|----|

F9 Did this injury limit your normal activities for one day or more?

- f9**
- | | | | |
|----------------------------|-----|----------------------------|----|
| ☐ 1 | Yes | ☐ 2 | No |
|----------------------------|-----|----------------------------|----|

F10 How were you injured?

- f10n1** ☐ Assault (punch, push or kick)
- f10n2** ☐ Other blunt (non-sharp) force
- f10n3** ☐ Gun shot
- f10n4** ☐ Stab/cut
- f10n5** ☐ Fall (not pushed)
- f10n6** ☐ Fire, heat, scald
- f10n7** ☐ Near-drowning
- f10n8** ☐ Poisoning
- f10n9** ☐ Bite or sting (animal, insect)
- f10n10** ☐ Choking
- f10n11** ☐ Other



F11 What was the location at which your most serious non-traffic related injury occurred?

- f11n1** ☐ Home
- f11n2** ☐ Sports facility
- f11n3** ☐ Workplace (agricultural)
- f11n4** ☐ Workplace (non-agricultural)
- f11n5** ☐ Other

F12 What was the nature of your non-traffic injury?
(you can choose more than one response)

- f12n1 ☐ Fracture
 f12n2 ☐ Sprain, strain or dislocation
 f12n3 ☐ Cut, bite or open wound
 f12n4 ☐ Bruise or superficial injury
 f12n5 ☐ Burn/scald
 f12n6 ☐ Concussion
 f12n7 ☐ Organ system (internal) injury
 f12n8 ☐ Other

(0= Response not chosen, 1=Response
 chosen) (If no response is chosen for any
 of the options in F12=0)

F13 Was this non-traffic injury?
(cross one box that fits best)

- f13 ☒ 1 Unintentional
☐ 2 Intentional by another person
☐ 3 Intentional (not involving another person)

-9 = missing



G Your lifetime health history

G1 In your life have you ever experienced a fracture to the areas of your body mentioned below?
 If so please place a cross in the Yes box and indicate the age at which the fracture occurred.
 (for bones broken multiple times put your age for the most recent time)

(0= Response not chosen, 1=Response
 chosen) (If no response is chosen for any
 of the options=0)

Don't answer this question if you have never had a fracture → ..go to G2

Bone Broken	Yes	Age when broken
<u>Example:</u> Wrist (fractured at age 12)	☒	1 2 -9=missing
Finger/Toe g1n1a	0, 1	g1n1b Years
Wrist g1n2a	0, 1	g1n2b Years
Arm g1n3a	0, 1	g1n3b Years
Collarbone g1n4a	0, 1	g1n4b Years
Rib g1n5a	0, 1	g1n5b Years
Skull g1n6a	0, 1	g1n6b Years
Face/Jaw/Nose g1n7a	0, 1	g1n7b Years
Neck g1n8a	0, 1	g1n8b Years
Back g1n9a	0, 1	g1n9b Years
Pelvis g1n10a	0, 1	g1n10b Years
Leg g1n11a	0, 1	g1n11b Years
Ankle g1n12a	0, 1	g1n12b Years
Other g1n13a	0, 1	g1n13b Years

G2 As a result of a diagnosis by a doctor, have you ever been told that you have any of the conditions listed below. If so cross the box and write in your age when the diagnosis was first made (you can chose more than 1 answer)

If you have never been diagnosed with this disease do not place a cross in the box

(0= Response not chosen, 1=Response chosen) -9=missing (0 = no text, 1 = text)

Disease	Yes	Age when broken	Hospital/Institution/Clinic where you were diagnosed
<u>Example:</u> Measles (diagnosed by Doctor when you were 14)	✕	14 Years	Krabi Hospital
Diabetes (need to use insulin)g2n1a	0, 1	g2n1b	g2n1c
Diabetes (do not need insulin)g2n2a	0, 1	g2n2b	g2n2c
High cholestrol/high blood lipidsg2n3a	0, 1	g2n3b	g2n3c
High blood pressure g2n4a	0, 1	g2n4b	g2n4c
Ischemic (coronary) heart diseaseg2n5a	0, 1	g2n5b	g2n5c
Cerebrovascular disease (stroke)g2n6a	0, 1	g2n6b	g2n6c
Liver cancer g2n7a	0, 1	g2n7b	g2n7c
Lung cancer g2n8a	0, 1	g2n8b	g2n8c
Stomach cancer g2n9a	0, 1	g2n9b	g2n9c
Colon-rectum cancer g2n10a	0, 1	g2n10b	g2n10c
Breast cancer g2n11a	0, 1	g2n11b	g2n11c
Other cancers g2n12a	0, 1	g2n12b	g2n12c
Goiter/Thyroid disease g2n13a	0, 1	g2n13b	g2n13c
Epilepsy g2n14a	0, 1	g2n14b	g2n14c
Liver disease (not cancer) g2n15a	0, 1	g2n15b	g2n15c
Kidney disease g2n16a	0, 1	g2n16b	g2n16c
Depression/anxiety g2n17a	0, 1	g2n17b	g2n17c
Arthritis g2n18a	0, 1	g2n18b	g2n18c
Chronic bronchitis/lung diseaseg2n19a	0, 1	g2n19b	g2n19c
Asthma g2n20a	0, 1	g2n20b	g2n20c
Malaria g2n21a	0, 1	g2n21b	g2n21c
Dengue fever g2n22a	0, 1	g2n22b	g2n22c
Tuberculosis g2n23a	0, 1	g2n23b	g2n23c
Other disease g2n24a (specify).....	0, 1	g2n24b	g2n24c

H Tobacco, alcohol and transport



H1 Are you a current smoker

h1b

- h1a ☐ 1 Yes..if yes, how many cigarettes per day
- ☐ 2 No, I used to smoke but have stopped completely
- ☐ 3 No, I have never smoked
-9 = missing

H2 In a typical week how many alcoholic drinks would you have?

h2 glasses per week -9 = missing

H3 On how many days a week do you usually drink?

h3 days per week -9 = missing
(put the number zero 0 if you don't drink)

H4 During the last 12 months have you driven a motor vehicle after consuming 3 or more glasses of alcohol

- h4 ☐ 1 Yes -9 = missing
- ☐ 2 No
- ☐ 3 Do not normally drive

H5 Which of the following do you, or any member of your household, own? (you can choose more than one response)(0=Response not chosen,1=chosen ,allblank=0)

- h5n1 ☐ Bicycle h5n2 ☐ Motorbike
- h5n3 ☐ Car/pick-up/van ☐ Truck h5n4
- h5n5 ☐ Boat h5n6 ☐ No vehicle owned

H6 For personal transport during the last 12 months how often do you...?

	Always	Sometimes	Never	Not applicable
Use car safety belt <u>Front Seat</u> h6n1	1	2	3	4 No safety belt
Use car safety belt <u>Back Seat</u> h6n2	1	2	3	4 No safety belt
Ride back step of 'song taew' h6n3	1	2	3	4 Don't use 'song taew'
Ride in back of open truck or pick-up h6n4	1	2	3	4 Don't ride that way
Use motorcycle helmet h6n5	1	2	3	4 Don't use motorcycle
Ride on motorcycle with 3 or more people h6n6	1	2	3	4 Don't use motorcycle

-9=missing

R The following questions are to be answered by females only



R1 How many babies have you given birth to?

r1 (If none put 0 0) -9=missing

R2 Please cross the appropriate box if you have EVER used any of the following hormonal contraceptives (you can cross more than one box)

- r2n1 ☐ Never used any of these
- r2n2 ☐ Injections every month
- r2n3 ☐ Injections every 3 months
- r2n4 ☐ Contraceptive implant eg. Implanon, Norplant
- r2n5 ☐ Oral contraceptive pill ☐ Other r2n6
- (0= Response not chosen, 1=Response

chosen)(All options blank at R2=0

R3 Please cross the appropriate box if you are CURRENTLY using any of the following hormonal contraceptives

- r3 ☐ 1 Not currently using any of these
- ☐ 2 Injections every month -9=missing
- ☐ 3 Injections every 3 months
- ☐ 4 Contraceptive implant eg. Implanon, Norplant
- ☐ 5 Oral contraceptive pill ☐ 6 Other

R4 If you are currently using a contraceptive pill, implant or injections, how long have you used it for?

r4 years (if less than one year please put zero 0 0) -9=missing



We would like to thank all respondents for their cooperation and assistance



Questionnaire

Thai Health Research Project 2013



Dear Thai Cohort Study members

With all of your much valued help our Thai Health Research Project has achieved substantial success. Analysing the information you have provided in your questionnaire responses has helped us understand better the risks to Thai peoples' health.

It is now time for us to follow up again on the health of our members. The further information you provide here will help us assess the health of Thai people and be of benefit to all of Thai society. The project follows strict ethical standards and all of your personal information will be held in the strictest confidence. Your name and address will be kept separately from your other data and will only be used to contact you. Your continued involvement in this project is completely voluntary, and if you wish to withdraw at any time please inform us.

If **you are the person whose name appears on the document above** and you are willing to continue participating in this health research project based at Sukhothai Thammathirat Open University please write your name and sign this form below. When you have completed the questionnaire please return it in the envelope included here. You do not need to attach a stamp.

(Name)..... Date...../...../.....

(Mr/Mrs/Miss)

If you have any doubts or concerns or need more information on the project please contact us on 02-5047780 during business hours. Thanks and regards.

(Associate Professor Sam-ang Seubsman)
Director Thai Health Research Project

This page will be separated
and treated as confidential

Your assistance in filling out this form is very important for the success of our research project. We need to know if your name, address or other details have changed from those shown on the front of the envelope.

Have you changed your **name-surname, address or telephone number** from those shown on the front cover of this questionnaire?

Please place a cross **×** in the appropriate boxes ☐. Please use a blue or black pen

☐ **Have not changed** name-surname, address or telephone number

**Please go to the instructions
at the top of the next page**

☐ **There has been a change** to my personal information as follows

☐ **Name-surname** ☐ **Address** ☐ **Telephone number**

Please give details below

First Name..... Family Name

Family Name..... Moo Ban Soi

Road..... Tambol/Kwang District/Khet

Province..... Postcode

Home Tel..... Office Tel.....

Mobile..... Email.....

Other contact person (if we cannot contact you)

First Name..... Family Name

Family Name..... Moo Ban Soi

Road..... Tambol/Kwang District/Khet

Province..... Postcode

Home Tel..... Office Tel.....

Mobile.....



Please keep a record of your member code (TCSID) from the front of the envelope to use as a reference in any future communication with the Thai Health Risk Transition Study

**This page will be separated
and treated as confidential**

Instructions: Use a blue or black pen to put a cross ✕ in the ☐ next to the selected choice to get to this image . Select one answer **except** when told “**more than** one answer can be given.” For numeric answers, write number(s) **clearly** in the box(es) - one number per box. Eg

2	4



Information on you and your work

A1 Sex ☐ Male ☐ Female

A2 When were you born (according to your Citizen ID Card)

Day Month Year (B.E.)

(eg

1	5

 /

0	1

 /

2	5	1	3

 if born 15 January 2513 please put)

A3 Where is your current residence located?

☐ Countryside ☐ City/town

A4 How long have you lived at your current residence?

 years (eg if you have lived there 3 years please

write

 Years)

A5 How far in kilometres is it from your current residence to each of the following places? (kms)

Distance Place	Less than 5 kms	5-10 kms.	11-20 kms	More than 20 kms
Supermarket/ minimart	☐	☐	☐	☐
ATM	☐	☐	☐	☐
Hospital	☐	☐	☐	☐
Post office	☐	☐	☐	☐
District office	☐	☐	☐	☐
School	☐	☐	☐	☐
Traffic light	☐	☐	☐	☐
Fresh market	☐	☐	☐	☐
Bus stop	☐	☐	☐	☐
Motorcycle taxi stand	☐	☐	☐	☐
Internet cafe	☐	☐	☐	☐



A6 In the past 5 years, has the area where you currently live become more urbanized?

☐ Yes ☐ No ☐ Unsure

A7 How many people live at your current residence?

 people (including you)

(eg if there are 3 people please put

)

A8 At present do you have any paid employment?

☐ Yes ☐ No → Go to question A14

A9 At present how many hours of paid work do you do per week?

 hours/week

A10 How secure do you feel about your job or career future in your current occupation?

☐ Not at all secure ☐ Moderately secure
☐ Secure ☐ Extremely secure

A11 Which of the following best describes your primary occupation? (Please choose only one answer)

☐ Senior manager ☐ Middle manager
☐ Professional (eg accountant, doctor, academic)
☐ Skilled worker (eg carpenters, hairdresser, craftsman)
☐ Office assistant
☐ Agricultural or fisheries worker
☐ Factory or assembly worker
☐ Elementary worker (non-physical) (eg courier)
☐ Elementary worker (physical) (eg construction)
☐ Other, please explain.....

A12 In the past 12 months, have you experienced uncomfortably hot temperatures in your workplace arising primarily from one of the following causes?

(Please choose only one answer)

- ☐ I am not bothered by high temperatures at work
- ☐ Heat from working outdoors
- ☐ Heat from machinery or production processes
- ☐ Heat from working in a vehicle
- ☐ Heat from work in a stuffy/poorly ventilated building
- ☐ Other, please explain.....

A13 In the past 12 months, when you experienced the workplace heat exposure described in question A12, what was your reaction? (You may choose more than one answer)

- ☐ No reaction
- ☐ Mild discomfort
- ☐ Prickly heat/ heat rash
- ☐ Headache/migraine
- ☐ Nausea or vomiting
- ☐ Severe dehydration
- ☐ Dizziness/ fainting with sweating
- ☐ Heat stroke (disorientation /elevated body temp



but no sweating)

- ☐ Muscle cramps
- ☐ Low blood pressure

A14 What is your personal average monthly income?

- ☐ ≤3,000 baht
- ☐ 3,001 - 7,000 baht
- ☐ 7,001 - 10,000 baht
- ☐ 10,001 - 20,000 baht
- ☐ 20,001 - 30,000 baht
- ☐ > 30,000 baht

A15 What is your household's average monthly income?

- ☐ ≤3,000 baht
- ☐ 3,001 - 7,000 baht
- ☐ 7,001 - 10,000 baht
- ☐ 10,001 - 20,000 baht
- ☐ 20,001 - 30,000 baht
- ☐ > 30,000 baht



A16 What is your highest level of education (not including any current studies)?

- ☐ Junior high school or equivalent
- ☐ Completed high school or equivalent
- ☐ Post-high school diploma or certificate
- ☐ Bachelor or higher university degree

A17 What is your current marital status? (Please choose only one answer)

- ☐ First marriage
- ☐ Remarried
- ☐ Separated (but not divorced)
- ☐ Divorced
- ☐ Widowed
- ☐ Never married

Go to question A19

A18 If not currently married, do you have a partner?

- ☐ Yes and we live together
- ☐ Yes but don't live
- ☐ Don't have a partner

A19 How tall are you? cms (without shoes)

A20 What is your weight now? kgs

(eg if your weight is 62 kgs write)

A21 Do you currently care for a chronically ill/disabled/ or frail family member or other person you know?

- ☐ Yes
- ☐ No

Go to question B1

A22 How many hours per week do you care for this chronically ill/disabled/or frail person?

hours/ week

A23 How many years have you cared for the person mentioned above? years

A24 What type/s of care do you provide to the person mentioned above?

(You may choose more than one answer)

- ☐ Help prepare food or eat
- ☐ Help bathe
- ☐ Help getting dressed
- ☐ Mobility (moving the person)
- ☐ Help going to temples/attending religious activities
- ☐ Shopping and/or providing daily food
- ☐ Emotional support/cheering up
- ☐ Cognitive care (helping to understand)
- ☐ Financial support
- ☐ Other



Your general health

B1 Overall how would you rate your health in the past 4 weeks?

- ☐ Excellent ☐ Very good ☐ Good
☐ Fair ☐ Poor ☐ Very poor

B2 During the past 4 weeks, how much did physical health problems limit your usual physical activities

(such as walking or climbing stairs)?

- ☐ Not at all ☐ Very little
☐ Some ☐ Quite a lot
☐ Could not do physical activities

B3 During the past 4 weeks, how much difficulty did you have doing your daily work, both at home and away from home, because of your physical health?

- ☐ None at all ☐ A little bit
☐ Some ☐ Quite a lot
☐ Could not do daily work

B4 How much bodily pain have you had during the past 4 weeks?

- ☐ None ☐ Very mild ☐ Mild
☐ Moderate ☐ Severe ☐ Very severe

B5 During the past 4 weeks, how much energy did you have?

- ☐ Very much ☐ Quite a lot ☐ Some
☐ A little ☐ None

B6 During the past 4 weeks, how much did your physical health or emotional problems limit your usual social activities with family or friends?

- ☐ Not at all ☐ Very little
☐ Somewhat ☐ Quite a lot
☐ Could not do social activities

B7 During the past 4 weeks, how much have you been bothered by emotional problems *(such as feeling anxious, depressed or irritable)?*

- ☐ Not at all ☐ Slightly ☐ Moderately
☐ Quite a lot ☐ Extremely

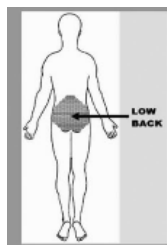
B8 During the past 4 weeks, how much did personal or emotional problems keep you from doing your usual work, school or other daily activities?

- ☐ Not at all ☐ Very little
☐ Somewhat ☐ Quite a lot
☐ Could not do daily activities

B9 In the past 4 weeks, to what extent has your health limited you in any of the following physical activities?

Limitation for the following physical activities	Not at all	A little	A lot
Climbing a flight of stairs	☐	☐	☐
Walking one hundred metres	☐	☐	☐
Bending, kneeling or stooping	☐	☐	☐
Dressing yourself	☐	☐	☐

B10 In the past 4 weeks, have you had pain in your low back *(in the area shown in the diagram)?*



☐ Yes

☐ No → [Go to question B12](#)

B11 If yes, was this pain bad enough to limit your usual activities or change your daily routine for more than one day?

- ☐ Yes ☐ No

B12 Adults can have up to 32 natural teeth. How many**of your own teeth do you have?**

- ☐ None
 ☐ 1-5 teeth
☐ 6-19 teeth
 ☐ 20 teeth or more

**B13 Do your teeth or dentures currently cause you....***(You may choose more than one answer)*

- ☐ Discomfort speaking
 ☐ Discomfort swallowing
☐ Discomfort chewing
 ☐ Loss of social confidence
☐ Pain
 ☐ None of these

**Your Life**

C1 How much support do you feel you get from each of the following groups. *(please place a cross X in the box which best applies to you for each question)*

	Very little	A little	Quite a lot	A lot	Not applicable
Family	☐	☐	☐	☐	☐
Neighbours	☐	☐	☐	☐	☐
Friends	☐	☐	☐	☐	☐
Employee/ supervisor	☐	☐	☐	☐	☐

C2 In the past 4 weeks how much of the time did you feel...? *(please place a cross X in the box which fits best for each question)*

Your feelings <i>(in the past 4 weeks)</i>	All of the time	Most of the time	Some of the time	A little of the time	None of the time
...so sad nothing could cheer you up?	☐	☐	☐	☐	☐
...nervous?	☐	☐	☐	☐	☐
...restless or fidgety?	☐	☐	☐	☐	☐
...hopeless?	☐	☐	☐	☐	☐
...everything was an effort?	☐	☐	☐	☐	☐
...worthless?	☐	☐	☐	☐	☐
...happy?	☐	☐	☐	☐	☐

C3 How often do you feel self-conscious or worried in the company of others because of your weight?

- ☐ Often
 ☐ Sometimes
 ☐ Never

C4 Regarding your current body size: Do you feel you need to

- ☐ Gain weight
 ☐ Lose weight
 ☐ Stay the same



C5 In the past 12 months, have you modified your diet to ☐ Gain weight ☐ Lose weight ☐ Did not modify diet

C6 How often do you have trouble controlling your food intake? ☐ Often ☐ Sometimes ☐ Never

C7 Thinking about your own life and personal circumstances, how satisfied are you with...

(Cross box on 0 → 10 scale that fits best for each question)

Satisfaction with:	Completely Dissatisfied ←————→ Completely Satisfied										
	0	1	2	3	4	5	6	7	8	9	10
...your standard of living?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
...how safe you feel?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
...feeling part of your community?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
...your life as a whole?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
...the amount of spare time you have?	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

C8 Generally speaking, how much would you say that most people can be trusted?

- ☐ Most people can be trusted ☐ You must be wary of people at all times

C9 How much of an effect did the flood crisis in 2011 have on your physical possessions (house or belongings)?

- ☐ A lot ☐ Some effect ☐ Little effect ☐ No effect

C10 How much of an effect did the flood crisis in 2011 have on your mental health?

- ☐ A lot ☐ Some effect ☐ Little effect ☐ No effect

C11 In general in 2012 what impact have floods had on you when compared with 2011?

- ☐ More than 2011 ☐ Less than 2011 ☐ About the same as 2011 ☐ Did not have any effect



D Your food and physical activity

D1 How many serves of vegetables do you eat per day? serves/day Eg if you eat 3 per day please put
(for vegetables 1 serve = 1/2 cup of cooked vegetables or 1 cup of raw vegetables)

D2 How many serves of fruit do you eat per day? serves/day Eg if you eat 5 serves per day please put
(for fruit 1 serve = 1 banana, 1 slice of papaya or 1 cup of diced pieces of fruit)

D3 How many teaspoons of fish sauce do you add to your food in an average day? teaspoons per day
if you don't add fish sauce at all please put

D4 How many teaspoons of sugar do you add to your meals and drinks in an average day? teaspoons per day
if you don't add sugar at all please put

D5 Have you ever seen "nutrition labels" on food?

- ☐ I have seen them and have read them ☐ I have seen them but have not yet read one ☐ I am unaware of them

D6 How often do you use information from nutrition labels on food products to assist your food purchasing decisions?

- ☐ Every time I shop ☐ Often ☐ Sometimes
☐ Seldom ☐ Never



D7 How well do you understand the information presented on food “nutrition labels”?

- ☐ I understand fully
 ☐ I understand most of the information
☐ I understand some of the information
 ☐ I do not understand the information but I know it has
☐ I don't understand the information or its potential benefit



D8 Would you like to see more nutrition labeling on foods?

- ☐ Yes
 ☐ No
 ☐ Don't know

D9 On average how often do you eat the following types of food? *(Please cross the one box which fits best for each food type)*

	Never or less than monthly	1-3 times/month	1-2 times/week	3-6 times/week	Daily or more
Food or dessert with coconut milk	☐	☐	☐	☐	☐
Deep fried food	☐	☐	☐	☐	☐
Instant foods eg instant noodles	☐	☐	☐	☐	☐
Fermented/ salted raw food eg crab, fish	☐	☐	☐	☐	☐
Fermented fruit/ vegetable	☐	☐	☐	☐	☐
White rice or white sticky rice	☐	☐	☐	☐	☐
Brown or combined brown and white rice	☐	☐	☐	☐	☐
Fish and fish products	☐	☐	☐	☐	☐
Soft drink (eg 7-Up, coke, pepsi)	☐	☐	☐	☐	☐
Other sweetened drinks (eg iced tea or coffee, sweetened herb drinks)	☐	☐	☐	☐	☐
Milk – fresh, carton or powder	☐	☐	☐	☐	☐
Vitamins or food supplements	☐	☐	☐	☐	☐
Fast food (Western style/farang) eg hamburger, pizza	☐	☐	☐	☐	☐
Western bakery products eg cake, cookies	☐	☐	☐	☐	☐

D10 On your past normal day (ie not a day off or weekend), **how many times did you have a meal?** **times/day**
(please include meals and snacks)

D11 In the past 7 days, how many times did you eat a main meal alone? **times/day**

D12 When you eat alone do you eat more, less or the same as when you eat with others?

- ☐ More
 ☐ Less
 ☐ About the same

D13 How much of the following types of exercise do you do in a typical week?

(If you exercise 3 times per week please put **0 3**)

If you don't do that type of exercise at all please put **0 0**)



Walking continuously for at least 10 minutes (for work, recreation, exercise or to get from place to place)	times per week
Vigorous physical activities for more than 20 minutes (that made you breathe harder or puff and pant)	times per week
Moderate physical activities for more than 20 minutes (like social tennis, golf, gentle swimming or work around the house or other work)	times per week

D14 How often do you do household cleaning or gardening work?

- ☐ Seldom or never
 ☐ 1-3 times/month
 ☐ Once or twice/week
☐ 3-4 times/week
 ☐ Everyday or almost everyday



D15 How many hours per day (ie per 24 hours) do you usually spend on the following activities?

Activities	Duration
Standing for any purpose at all (eg for work, while socializing etc.)	hours/day
Sitting for any purpose (eg reading, resting, writing, thinking, TV, or computer)	hours/day
Sleeping (if you regularly sleep during the day include this also)	hours/day
Watching TV and/or playing computer games?	hours/day



Your injuries



Your injuries – traffic related



E1 In the past 12 months, how many times did you get

injured in a traffic crash

- ☐ Never
 ☐ One
 ☐ Two
 ☐ Three
 ☐ Four or more

Go to question E7

E2 When you experienced your most serious traffic related

injury did you receive medical care?

- ☐ Yes
 ☐ No

E3 Did this injury limit your normal activities for one day or more?

- ☐ Yes
 ☐ No

E4 When this injury occurred what was your role?

- ☐ Driver
 ☐ Passenger
 ☐ Pedestrian

Go to question E6

E5 Type of vehicle you were in or on as driver or passenger?

- ☐ Bicycle
 ☐ Motorbike
 ☐ Bus, van, tour coach
 ☐ Car/pick-up
 ☐ Other (eg train, plane, boat)

E6 What was the other party in the collision causing

the traffic-related injury?

- ☐ Bicycle ☐ Motorbike
- ☐ Bus, van, tour coach
- ☐ Car/pick-up
- ☐ Other vehicle (eg train, boat)
- ☐ Pedestrian
- ☐ Animal (eg dog)
- ☐ Other object not vehicle (eg tree, road, wall)

Your injuries – **non-traffic-related**



E7 In the past 12 months, how many times did you have a NON-TRAFFIC injury?

- ☐ Never ☐ One ☐ Two ☐ Three ☐ Four or more

Go to question **F1**

E8 When you experienced your most serious non-traffic-related injury did you receive medical care?

- ☐ Yes ☐ No

E9 Did this injury limit your normal activities for one day or more?

- ☐ Yes ☐ No

E10 How were you injured?

- ☐ Assault (punch, push or kick)
- ☐ Other blunt (non-sharp) force
- ☐ Stab/cut ☐ Gunshot
- ☐ Fall (not pushed) ☐ Lifting heavy object
- ☐ Fire, heat, scald ☐ Near-drowning
- ☐ Bite or sting (animal, insect) ☐ Poisoning
- ☐ Choking ☐ Other

E11 What was the location at which your most

serious non-traffic related injury occurred?

- ☐ Home
- ☐ Sports facility
- ☐ Workplace (agricultural)
- ☐ Workplace (non-agricultural)
- ☐ Other

E12 What was the nature of your most serious

non-traffic injury? (You may choose more than one answer)

- ☐ Fracture
- ☐ Sprain, strain or dislocation
- ☐ Cut, bite or open wound
- ☐ Bruise or superficial injury
- ☐ Burn/scald
- ☐ Concussion
- ☐ Organ system (internal) injury
- ☐ Other

E13 How did this non-traffic injury occur?

(Please choose only one answer)

- ☐ Unintentional/ accident
- ☐ Intentional by another person
- ☐ Intentional (not involving another person)





F1 Have you ever received a confirmed diagnosis from a doctor that you definitely have any of the following diseases?

Health condition	Definitely have disease	Doctor said I am at risk of the disease	Don't have the disease
Diabetes	☐	☐	☐
High cholesterol/high blood lipids	☐	☐	☐
High blood pressure	☐	☐	☐
Ischemic (coronary) heart disease	☐	☐	☐
Cerebrovascular disease (stroke)	☐	☐	☐
Liver cancer	☐	☐	☐
Lung cancer	☐	☐	☐
Stomach cancer	☐	☐	☐
Colon-rectum cancer	☐	☐	☐
Breast cancer	☐	☐	☐
Other cancers	☐	☐	☐
Kidney disease	☐	☐	☐
Other disease (specify).....	☐	☐	☐

F2 What health insurance scheme/s covers you at present

and for how long have you been covered? (please cross all boxes which apply)(If you have been covered by a scheme for less than one year please put ☐ 0 ☐ 1)

Type of health insurance	Length of coverage
☐ Don't have insurance	
☐ Civil Servants Coverage scheme	Years
☐ Employer provided coverage	Years
☐ Private health insurance	Years
☐ Social Security Scheme	Years
☐ Universal Coverage Scheme	Years
☐ Other.....	Years

F3 In the past 12 months how many times have you used the following types of health services? (You may choose more than one answer)

Health service type	Number of visits (past 12 months) Eg if you visited once in the past year please put ☐ 0 ☐ 1 times
Government health centre	times
Community hospital	times
Private health clinic	times
Government hospital	times
Private hospital	times
Traditional medicine	times
Pharmacy	times
Other.....	times



Smoking, alcohol and transport

G1 Are you a **current** smoker?

☐ No ☐ Yes and I smoke cigarettes per day

G2 Please describe your current alcohol drinking?

☐ Don't drink ☐ Used to drink but quit
☐ Drink in social situations, about glasses/week
☐ Current regular drinker of about glasses/ day

G3 In the **past 12 months** have you ever driven a vehicle after consuming **3 or more glasses of alcohol**?

☐ Yes ☐ No
☐ Don't normally drive



G4 In the **past 12 months**, for personal transport how often did you...?

	Always	Sometimes	Never	Not applicable	
Use car safety belt (<u>front seat</u>)	☐	☐	☐	☐	No safety belt or don't ride in front seat
Use car safety belt (<u>back seat</u>)	☐	☐	☐	☐	No safety belt or don't ride in back seat
Ride on back step of "song thaew"	☐	☐	☐	☐	Don't use "song thaew"
Ride in back of open truck/pick up	☐	☐	☐	☐	Don't use such vehicle
Use motorcycle helmet	☐	☐	☐	☐	Don't use motorcycle
Ride on motorcycle with 3 or more people	☐	☐	☐	☐	Don't use motorcycle



Birth and contraception (for cohort member women only to answer)

(Male cohort members please ignore this section)



H1 How many babies have you ever given birth to? Babies (If you have never given birth please put)

H2 Please tell us about your past and present use of the following contraceptives (If you have used for less than one year please put)

Have you ever taken or used the following types of hormonal contraceptives?		Age started using?	Age past used? (or age now if still using)	How long did you use it altogether? (don't count periods of non-use)
Oral contraceptive pill	☐ No			
	☐ Yes →	yrs	yrs	yrs
Injections every three months (depo provera)	☐ No			
	☐ Yes →	yrs	yrs	yrs
Contraceptive implant under the skin (may past 3-5 years)	☐ No			
	☐ Yes →	yrs	yrs	yrs