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Predictors of increasing waist circumference in an Australian population

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Abstract

Objective: To identify predictors of increasing waist circumference (WC) over a 5-year period in a contemporary population of Australian adults.
Design: Longitudinal national cohort of adults participating in the Australian Diabetes, Obesity and Lifestyle Study (AusDiab).
Settings: Australian adults in 2000 and 2005.
Subjects: A total of 2521 men and 2726 women aged ≥25 years at baseline who participated in AusDiab and provided anthropometric measurements at baseline (1999–2000) and follow-up (2005).
Results: A ≥5 % increase of baseline WC occurred in 27 % of men and 38 % of women over the 5-year period. In the multivariate analysis of the total population, there was a higher risk of ≥5 % gain in baseline WC in women, younger people, people with a lower baseline WC, people who never married compared with married/*de facto*, current smokers compared with never smokers, people with a poorer diet quality and people with a low energy intake. However, there was no significant association with many expected predictors of waist gain such as physical activity. There were some associations between other lifestyle factors and change of WC by sex, age, level of education and across WC categories, but the associations differed across these groups.
Conclusions: A ≥5 % increase of baseline WC occurred in a significant proportion of men and women over the 5-year period. Of the behavioural factors, poor diet quality was the key predictor of the ≥5 % increase of baseline WC in this cohort. The findings highlight the need to understand better the causal role of lifestyle in regard to increasing WC over time.

Keywords
Waist circumference
Weight gain
Obesity
Predictors
Diet

Recent reports have shown faster increases in waist circumference (WC) than BMI[1,2], suggesting that the nature of excess body weight may be changing over time to one of greater central adiposity, rather than a more peripheral distribution of body fat[1,2]. This has significant implications, considering that WC measures the central or abdominal distribution of excess body fat, which appears to be strongly correlated with metabolic and cardiovascular risk[3,4]. However, little is known about the drivers of increases in WC.

Few studies have examined the predictors of increasing weight in adults, and we are not aware of any that have examined a range of behavioural lifestyle factors potentially predictive of abdominal weight gain. Table 1 summarises those studies exploring predictors of change in BMI, weight and/or WC. The only study we were able to source that explored behavioural predictors of change in WC examined a limited selection of predictors in women[5]. Previous cross-sectional analyses have found lifestyle factors such as higher television (TV) viewing time and lower levels of physical activity to be associated with higher WC[6–9], and studies analysing predictors of gain in BMI/weight have found associations with factors such as higher TV viewing time and lower levels of physical activity[5,10–14]. Sternfeld *et al.*[5] found that low levels of total physical activity were associated with increasing WC in their longitudinal analysis of American women. But for the most part, it is unknown whether such behavioural factors are also driving increases in WC over time. A set of behavioural factors with which to define an 'at risk' state for the onset of abdominal weight gain would be useful, as the development of effective prevention strategies requires a better understanding of the causal role of lifestyle and health behaviours with regard to increasing WC over time.

The aim of the present study was to identify factors predictive of increasing WC – defined as a WC measurement at

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Table 1 Summary of literature exploring predictors of change in BMI, weight or WC in adults

Study	Year	Country	Age and sex of population	Measured variables	Key predictors of outcome	Follow-up (years)
French *et al.*[10]	1994	USA	Age (years); men and women (*n* 3552)	Weight	Weight loss: increased exercise Weight gain: history of participation in formal weight loss programme, dieting to lose weight at baseline, increased consumption of fries, dairy products, sweets and meat	2
HPFS[11]	1998	USA	40–75 years of age; men (*n* 19 478)	Weight	Weight loss: vigorous activity, being on a diet Weight gain: television viewing, eating between meals, quitting smoking and history of voluntary weight loss	2, 4, 6, 8
FTC[41]	1998	Finland	18–54 years of age, twin pairs; men and women (*n* 5867)	Weight	Weight gain: high level of stress at baseline Weight gain for women: low levels of life satisfaction and high score for neuroticism	6
POP[42]	2000	USA	20–45 years of age; men and women (*n* 1044)	Weight	Weight gain: dietary fat intake, low levels of physical activity Weight loss: high levels of physical activity, decreased food intake	3
CHNS[12]	2001	Seven provinces in China	20–45 years of age; men and women (*n* 2488)	BMI	Weight gain: light work related levels of physical activity	8
WHA[13]	2002	Australia	18–23 years of age; women (*n* 8726)	BMI	Weight maintenance: managerial/professional occupations, never married, currently studying, not mothers, less time sitting and overconsumption of takeaway food	4
EPIC[14]	2002	Germany	24–69 years of age for men and 19–70 years for women (*n* 17 369)	Weight	Weight gain: women – consumption of high-energy, high-fat food (fats, sauces, and meat); men – energy-dense foods (sweets) Weight loss: women – cereals	2
IRAS[43]	2003	USA	40–69 years of age; men and women (*n* 1194)	BMI, WC	Weight loss: diabetic state, high fasting insulin concentrations	5
SWAN[5]	2004	USA	42–52 years age of age; women (*n* 3064)	Weight, WC	WC gain: baseline age, follow-up time, low levels of physical activity, race, perceived health, health status, smoking Weight gain: follow-up time, low levels of physical activity, race, perceived health, health status and smoking	3
Janghorbani *et al.*[44]	2008	Iran	Mean age: 51·3 years; men and women with type 2 DM (*n* 12 650)	BMI	Weight loss: women, lower education, longer duration of DM, never smokers, insulin treatment regimen and higher HbA1c at baseline Weight gain: class II and III obesity at baseline	9·1

WC, waist circumference; HPFS, Health Professionals' Follow-up Study; FTC, Finnish Twin Cohort; POP, Malmo Diet and Cancer Prospective Cohort Study; CHNS, China Health and Nutrition Survey; WHA, Australian Longitudinal Study on Women's Health; EPIC, European Prospective Investigation into Cancer and Nutrition–Potsdam cohort; IRAS, Insulin Resistance Atherosclerosis Study; SWAN, Study of Women's Health Across the Nation; DM, diabetes mellitus.

follow-up ≥5 % of baseline WC – over a 5-year period in a cohort of Australian adults. Specifically, the study aimed at analysing the relationship between lifestyle behaviours including levels of physical activity, TV viewing time, smoking, alcohol consumption, energy intake, diet quality and portion size and change in WC.

Methods

Participants

The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) is a cross-sectional, national, population-based survey conducted during 1999–2000 of 11 247 Australian adults (aged ≥25 years). From the 17 129 eligible households, 20 347 adults completed a household interview and 11 247 (55·3 %) had a biomedical examination after an overnight fast, giving an overall response rate of 37 %[15]. The majority (87·9 %) of participants were born either in Australia or the UK; 96 % spoke English at home; 0·8 % were an Aboriginal or Torres Strait Islander[16]. In 2004–2005, all participants (*n* 11 247) were invited to a follow-up examination. Of the 10 788 participants eligible for follow-up testing in 2004–2005, 6537 (61 %) presented for the biomedical examination and/or blood tests[16].

At baseline and follow-up, questionnaires were administered, anthropometric measurements were taken and a fasting blood sample was collected. The AusDiab study methodology has been described in more detail previously[15,16]. In the present study, the sample population was defined as participants who attended at both baseline and follow-up and had measures of WC at both examinations (*n* 5247).

All survey participants provided informed consent. The study was approved by the ethics committees of the Baker IDI Heart and Diabetes Institute and Monash University.

Measures

Changes in WC between baseline and follow-up were divided into three categories. A gain in WC was defined as a follow-up WC measurement increase of ≥5 % in baseline WC. No change in WC was defined as a follow-up WC measurement of within 5 % in baseline WC, and a loss of WC was defined as a follow-up WC measurement decrease of >5 % in baseline WC. The following cut-offs to the WC measurements were also applied to classify people into 'low risk' (<94 cm for men; <80 cm for women), 'increased risk' (≥94–<102 cm for men; ≥80–<88 cm for women) and 'substantially increased risk' (≥102 cm for men; ≥88 cm for women)[17]. Ethnic-specific cut-off points for WC were not used in this analysis as the proportion of Asian participants at baseline was low (3·5 %) and not substantially different at follow-up.

Demographic attributes, smoking habits, educational attainment and history of ever being told of having had an angina, heart attack and stroke were assessed using an interviewer-administered questionnaire. Plasma diabetes status was determined by a blood sample undertaken during the physical examination[16].

Physical activity

Physical activity was measured by an interviewer-administered Active Australia questionnaire, which considered participation in predominantly leisure-time physical activities (including walking for transport) during the previous week[18]. Total physical activity time was calculated as the sum of time spent walking (if continuous and for ≥10 min) or performing moderate-intensity activity, plus double the time spent in vigorous-intensity physical activity. This double weighting has been used because of the need to reflect that participation in vigorous-intensity physical activity confers even greater health benefits than participation in moderate activity[19].

Television viewing time

Self-reported TV viewing time was calculated as the total time spent watching TV or videos in the previous week, and is considered a reliable and valid estimate of TV viewing time among adults[20].

Dietary quality

Dietary intake was assessed using a self-administered validated FFQ[21], which included seventy-four items (with ten frequency options), with additional questions on food habits, portion size and consumption of alcoholic beverages. Nutrient intakes from the FFQ was used to derive the Diet Quality Index (DQI)[22,23] and summarised to reflect ten dietary characteristics – total fat, saturated fat, dietary cholesterol, fruit, vegetables, grains, calcium, iron, dietary diversity and dietary moderation. Scores from each of the ten components were summed for a highest possible score of 100 points, which represents a best-scenario dietary quality (M Reeves, G Healy, D Dunstan *et al.*, unpublished results).

Portion size

The average daily serving sizes of potatoes, vegetables, steak and casserole/other meat were calculated as a single 'portion size factor' (PSF), which identified whether, on average, a median size serve was consumed (PSF = 1), more than the median (PSF > 1) or below the median (PSF < 1)[24].

Socio-economic Indexes for Areas – disadvantage

Socio-economic status was measured using an index of disadvantage code from the Socio-economic Indexes for Areas. The index is derived from attributes such as low income, low educational attainment, high unemployment and jobs in low-skilled occupations. The index is constructed so that high values reflect high socio-economic status (relative advantage) and low values reflect low socio-economic status (relative disadvantage)[25,26].

Statistical analyses

Logistic regression was used to predict the likelihood of a gain in WC compared to maintaining baseline WC. In Table 3, the results are presented for each predictor: (i) unadjusted; (ii) adjusted for sex and age; and (iii) adjusted for sex and age group plus key 'fixed' demographics, all demographics or all demographics plus all lifestyle predictors, depending on the specific predictor. Thus, those variables entered into the two multivariate logistic regression models in Table 3 were: sex and age group (model 1); sex and age group plus for variables marked 'a' – country of birth and Aboriginal and Torres Strait Islander status; for variables marked 'b' – everything listed under 'a' plus education, occupation, marital status, whether living in an Australian capital city; and for variables marked 'c' – everything listed under 'a' and 'b' plus baseline WC, physical activity, TV viewing, smoking status, diet quality, alcohol, energy intake and portion size (model 2). The variables entered into the multivariate logistic regression in subsequent tables and figures were those described by 'c' above, namely the country of birth, Aboriginal and Torres Strait Islander status, education, occupation, marital status, whether living in an Australian capital city, physical activity, TV viewing, smoking status, diet quality, alcohol, energy intake and portion size. The findings from the fully adjusted multivariate analyses are discussed in the 'Results' section.

Analyses were conducted using the STATA statistical software package version 9·0 (Intercooled Stata, StataCorp., College Station, TX, USA) and took into account the complex, two-stage, cluster sampling design of the AusDiab study.

Results

As shown in Table 2 (univariate results), people who underwent WC gain (≥5 % increase in baseline WC) had a lower mean baseline WC than the people who maintained baseline WC (within 5 % of baseline WC) and those who underwent WC loss (≥5 % loss in baseline WC). A higher proportion of women than men underwent WC gain and there was a higher proportion of people aged 25–54 years than those aged ≥55 years. White-collar workers were more likely to undergo WC gain than other occupational groups. Retirees and blue-collar workers were the least likely to undergo WC gain.

Counter-intuitively, people who underwent WC gain viewed less TV per week, had a lower energy intake and consumed smaller average portion sizes than people who maintained baseline WC or underwent a loss of baseline WC. People who underwent WC gain were more likely to be current smokers than never smokers or ex-smokers (Table 2).

Only people who underwent WC gain and WC maintenance have been included in the analyses to follow, as it is the comparison between these two groups in which we are interested. People who underwent WC loss are likely to be a heterogeneous group that has lost weight for a variety of reasons, including illness.

In the multivariate analysis of the total population (Table 3), people who underwent WC gain were more likely to be female, to have a lower baseline WC, to be aged 25–34 years than >35 years and to have been never married than married/*de facto*. Of the behavioural variables, people who underwent WC gain were more likely to be current smokers than never smokers, to have a poorer diet quality and to have a low energy intake. There was also a suggestion of a protective effect of a lower level of TV viewing. We explored whether the predictive effect of current smoking was driven by people quitting smoking over the 5-year period. For the fully adjusted multivariate analysis, compared with the never smokers the odds of WC gain for current smokers who continued smoking over the 5-year period and current smokers who quit over the 5-year period were 1·01 (95 % CI 0·80, 1·28) and 2·05 (95 % CI 1·34, 3·14). To ensure that the lack of association between other variables such as physical activity and WC gain was not due to the definition of change in WC, we undertook analyses using three different definitions of change in WC, and the results were similar. To ensure that the lack of association was not due to the choice of reference category, we undertook analyses including both WC losers and maintainers in the reference category, and the results were again similar. The results were also similar after adjustment for obesity-related diseases (plasma diabetes status and history of angina, heart attack and stroke).

To explore whether effect modification influenced the findings, we analysed the potential behavioural predictors of WC gain by sex and age. Figure 1 illustrates that in the multivariate analysis of men, there were no significant predictors of a gain in WC, although there was a suggestion of a protective effect of diet quality. In the multivariate analysis of women, those who underwent WC gain were more likely to be current smokers than never smokers, and there was a suggestion of a protective effect of diet quality.

Figure 2 illustrates that in the multivariate analysis of people aged 25–54 years, people who underwent WC gain were more likely to have a poorer diet quality. Comparing people aged 25–34 years and 35–44 years (data not shown), in the younger age group people who underwent WC gain were more likely to have a poorer diet quality and a low energy intake, whereas in the older age group people who underwent WC gain were more likely to watch 2–4 h/d of TV rather than <2 h/d. In people aged ≥55 years (Fig. 2), people who underwent WC gain were more likely to engage in higher levels of physical activity. In people aged ≥65 years (data not shown), people who underwent WC gain were more likely to engage in higher levels of physical activity.

We have stratified by WC category at baseline to explore whether the findings are affected by the choice of

Table 2 Proportion of participants in each category of WC change, by sociodemographic characteristics and behaviours (at baseline except where indicated)

Items	*n*	WC gain (*n* 1748; 33·31 %)		WC maintenance (*n* 2821; 53·76 %)		WC loss (*n* 678; 12·92 %)	
		Mean or %	SE	Mean or %	SE	Mean or %	SE
WC (cm)	5247	86·95	0·48	92·71	0·40	94·50	0·52
Demographic characteristics							
Sex (%)							
Men	2521	27·49	1·64	60·42	1·28	12·10	0·88
Women	2726	38·70	1·62	47·62	1·24	13·68	0·96
Age groups (%; years)							
25–34	392	38·27	2·32	45·66	2·30	16·07	1·80
35–44	1229	35·88	1·94	53·30	1·51	10·82	1·00
45–54	1630	36·87	1·80	51·29	1·37	11·84	1·12
55–64	1117	29·36	2·21	56·76	1·71	13·88	1·37
65–74	654	26·61	2·04	59·94	2·26	13·46	1·10
≥75	225	24·00	3·28	55·56	3·00	20·44	3·21
Country of birth (%)							
Australia/New Zealand	4065	34·12	1·53	53·28	1·11	12·60	0·76
UK/Northern Ireland	591	30·29	2·08	53·64	2·14	16·07	1·66
Other	591	30·80	2·70	57·19	2·62	12·01	1·32
Aboriginal and Torres Strait Islander status (%)							
Yes	40	25·00	–	70·00	–	5·00	–
No	5207	33·38	1·47	53·64	1·03	12·98	0·74
Completion of high-school education (%)							
Yes	2539	33·99	1·56	53·13	1·12	12·88	0·95
No	2708	32·68	1·69	54·36	1·36	12·96	0·83
Occupation (%)							
Professional	1654	34·22	2·05	54·05	1·63	11·72	0·96
White collar	846	40·90	2·11	48·46	1·70	10·64	1·57
Blue collar	717	27·75	1·77	58·30	1·56	13·95	1·29
Home duties	359	36·21	2·71	49·30	2·79	14·48	2·05
Unemployed, students	58	32·76	7·11	51·72	5·90	15·52	4·61
Retirees	587	28·62	2·22	58·09	1·93	13·29	1·55
Pensioners	1026	31·19	1·86	53·70	1·71	15·11	0·99
SEIFA – disadvantage (%)							
<1000	1757	32·56	–	54·52	–	12·92	–
≥1000	3490	33·70	1·66	53·38	1·13	12·92	0·85
Marital status (%)							
Married/*de facto*	4313	32·76	1·53	54·49	1·04	12·75	0·89
Widowed/separated/divorced	682	35·78	1·95	50·88	2·07	13·34	1·16
Never married	252	36·11	3·13	49·21	2·72	14·68	2·78
Living in an Australian capital city (%)							
Yes	3299	32·74	1·36	52·86	0·98	14·40	0·88
No	1948	34·29	1·77	55·29	1·08	10·42	1·14
Behavioural characteristics							
Physical activity time (h/week)	5247	4·79	0·20	4·75	0·16	4·43	0·24
TV viewing time (min/week)	5247	709·71	19·63	762·46	16·34	817·28	23·96
TV viewing time (%, h/d)							
<2	341	34·31	3·13	52·79	2·79	12·90	2·22
2–4	450	41·56	2·58	49·56	2·48	8·89	1·20
≥4	4446	32·41	1·44	54·26	1·06	13·33	0·76
Smoking status (%)							
Never smoker	3029	33·51	1·57	54·18	1·09	12·31	0·83
Ex-smoker	1605	31·40	1·84	54·58	1·61	14·02	1·02
Current smoker	613	37·36	2·11	49·59	2·23	13·05	1·38

Table 2 *Continued*

Items	*n*	WC gain (*n* 1748; 33·31 %)		WC maintenance (*n* 2821; 53·76 %)		WC loss (*n* 678; 12·92 %)	
		Mean or %	SE	Mean or %	SE	Mean or %	SE
Diet quality (DQI/100)	5247	66·44	0·44	66·90	0·40	67·71	0·52
Alcohol consumption (%)							
Current non-drinkers	732	30·46	2·23	54·10	1·84	15·44	1·65
Light drinkers	3181	34·80	1·48	52·85	1·08	12·35	0·73
Moderate to heavy drinkers	1334	31·33	1·91	55·77	1·46	12·89	1·09
Fruit consumption (per d; %)							
Do not eat fruit	100	39·00	4·98	47·00	4·50	14·00	3·64
<2	1105	32·94	1·90	53·67	1·84	13·39	1·19
≥3	4042	33·28	1·50	53·96	1·11	12·77	0·80
Vegetable consumption (per d; %)							
<2	62	32·26	6·04	58·06	6·11	9·68	3·60
3–4	4439	33·30	1·49	54·18	1·16	12·53	0·82
≥5	746	33·51	2·22	50·94	2·02	15·55	1·30
Energy intake (kJ/d)	5247	7962·83	73·21	8396·50	64·34	8376·00	143·77
Portion size	5247	1·16	0·01	1·20	0·01	1·19	0·02

WC, waist circumference; SEIFA, Socio-economic Indexes for Areas; TV, television; DQI, Diet Quality Index.

the comparator group – between people who underwent ≥5 % gain in WC and those who maintained their baseline WC, but who may have also gained WC recently (but before the survey period; Table 4).

Table 4 illustrates that in the multivariate analysis of people with a low-risk WC at baseline, people who underwent WC gain were more likely to watch 2–4 h/d of TV than <2 h/d. In people with increased-risk WC at baseline, people in the highest quartile of energy intake were less likely to undergo WC gain. In people with a substantially-increased-risk WC at baseline, people who underwent WC gain were more likely to watch <2 h/d of TV than ≥4 h/d, be current smokers than never smokers and to have a poorer diet quality.

Overall, there were few significant associations with behavioural predictors. The lack of associations in the low-risk group suggests that the choice of comparator groupings is appropriate, as people who were defined as having maintained their baseline WC are less likely in the low-risk group to have undergone a recent gain in WC. The relative lack of right skew in the distribution of gain in WC in people who did not undergo a change in baseline WC (data not shown) also supports this.

To test the sensitivity of our results to the definition of WC gain used, we conducted a series of analyses for the primary (total population) analysis using different definitions of gain in WC – a 5 % increase in WC *v.* the total population (including people with WC gain, WC maintenance and WC loss); a ≥2 % increase in WC *v.* a change of between <2 % and >2 %; and differences between quartiles of gain in WC (to explore absolute changes in WC). The results did not differ greatly from those presented here.

Discussion

An increase ≥5 % in baseline WC occurred in over a quarter of men and over a third of women between 2000 and 2005. Women, younger people, people who had never married and people with a lower baseline WC were more likely to gain ≥5 % in baseline WC. The key behavioural predictor of WC gain was poor diet quality.

Overall, the patterns were very similar by age and sex, with the exceptions of poor diet quality as a clear predictor of WC gain in people aged 25–54 years but not for people aged ≥55 years, and a high level of physical activity as a predictor of WC gain in the older age group but not in the younger age group. This finding of a high level of physical activity as a predictor of WC gain in older people may be a consequence of illness being associated with WC loss and lower levels of physical activity.

Previous studies exploring behavioural predictors of an increase in BMI and weight have found a range of predictive factors, including increased TV viewing time, consumption of energy-dense foods, consumption of meat and low levels of physical activity (see Table 1). The only study

Table 3 Univariate and multivariate associations of potential predictors of WC gain in total population

	Univariate		Multivariate†		Multivariate‡	
Items	OR	95% CI	OR	95% CI	OR	95% CI
WC[c]	0·97*	0·96, 0·97	0·97*	0·97, 0·98	0·97*	0·97, 0·98
Demographic characteristics						
Sex[a]						
Men	Ref.		Ref.		Ref.	
Women	1·79*	1·57, 2·04	1·79*	1·57, 2·04	1·79*	1·57, 2·03
Age groups[a] (years)						
25–34	Ref.		Ref.		Ref.	
35–44	0·80	0·63, 1·02	0·75*	0·59, 0·96	0·75*	0·59, 0·95
45–54	0·86	0·68, 1·09	0·82	0·65, 1·04	0·82	0·65, 1·04
55–64	0·62*	0·49, 0·77	0·59*	0·47, 0·73	0·59*	0·47, 0·73
65–74	0·53*	0·42, 0·66	0·51*	0·41, 0·64	0·51*	0·41, 0·64
≥75	0·52*	0·33, 0·80	0·50*	0·32, 0·78	0·50*	0·32, 0·78
Country of birth group[a]						
Australia/New Zealand	Ref.		Ref.		Ref.	
UK/Northern Ireland	0·88	0·72, 1·08	0·95	0·77, 1·18	0·95	0·77, 1·17
Other	0·84	0·66, 1·07	0·87	0·68, 1·12	0·86	0·67, 1·11
Aborginal and Torres Strait Islander status[a]						
Yes	Ref.		Ref.		Ref.	
No	1·74	0·69, 4·37	1·94	0·77, 4·91	1·97	0·78, 5·01
Completion of high-school education[b]						
Yes	Ref.		Ref.		Ref.	
No	0·94	0·82, 1·08	0·95	0·82, 1·10	0·94	0·80, 1·11
Occupation[b]						
Professional	Ref.		Ref.		Ref.	
White collar	1·33	1·09, 1·63	1·09	0·87, 1·36	1·11	0·89, 1·38
Blue collar	0·75*	0·63, 0·89	0·82*	0·68, 1·00	0·84	0·69, 1·03
Home duties	1·16	0·89, 1·52	0·86	0·64, 1·15	0·90	0·67, 1·20
Unemployed, students	1·00	0·53, 1·88	0·97	0·51, 1·83	0·97	0·52, 1·81
Retirees	0·78*	0·63, 0·96	1·03	0·76, 1·38	1·02	0·76, 1·37
Pensioners	0·92	0·73, 1·15	1·09	0·82, 1·46	1·09	0·83, 1·43
SEIFA – disadvantage						
<1000	Ref.		Ref.		Ref.	
≥1000	1·06	0·86, 1·30	1·06	0·86, 1·31	1·07	0·85, 1·34
Marital status[b]						
Married/*de facto*	Ref.		Ref.		Ref.	
Widowed/separated/divorced	1·17	0·98, 1·39	1·16	0·98, 1·38	1·15	0·96, 1·38
Never married	1·22	0·99, 1·50	1·30*	1·04, 1·63	1·30*	1·04, 1·61
Living in an Australian capital city[b]						
Yes	Ref.		Ref.		Ref.	
No	1·00	0·80, 1·26	1·00	0·79, 1·26	0·99	0·78, 1·26
Behavioural characteristics						
Physical activity time[c] (min/week)	1·00	0·99, 1·01	1·01	1·00, 1·02	1·01	1·00, 1·02
TV viewing time[c] (h/d)						
<2	Ref.		Ref.		Ref.	
2–4	1·29	0·97, 1·72	1·35	0·99, 1·84	1·34	0·99, 1·82
≥4	0·92	0·70, 1·20	1·05	0·79, 1·38	1·03	0·78, 1·36
Smoking status[c]						
Never smoker	Ref.		Ref.		Ref.	
Ex-smoker	0·93	0·82, 1·06	1·05	0·93, 1·19	1·04	0·91, 1·18
Current smoker	1·22	0·99, 1·49	1·28*	1·03, 1·59	1·25*	1·00, 1·55
Diet quality[c] (DQI/100) (mean, SE)	0·74	0·45, 1·23	0·59	0·34, 1·03	0·57*	0·33, 1·00
Alcohol consumption[c]						
Current non-drinkers	Ref.		Ref.		Ref.	
Light drinkers	1·17	0·98, 1·39	1·14	0·95, 1·36	1·12	0·94, 1·33
Moderate-heavy drinkers	1·00	0·84, 1·18	1·12	0·93, 1·35	1·03	0·86, 1·24
Fruit consumption[c] (per d)						
Do not eat fruit	Ref.		Ref.		Ref.	
<2	0·74	0·48, 1·14	0·70	0·45, 1·10	0·75	0·47, 1·19
≥3	0·74	0·49, 1·13	0·68	0·44, 1·06	0·78	0·49, 1·24
Vegetable consumption[c] (per d)						
<2	Ref.		Ref.		Ref.	
3–4	1·11	0·62, 1·96	1·17	0·65, 2·09	1·27	0·69, 2·33
≥5	1·18	0·64, 2·17	1·15	0·63, 2·12	1·25	0·67, 2·36
Energy intake[c] (kJ/d)§	0·96*	0·94, 0·97	0·98*	0·96, 1·00	0·97	0·95, 1·00
<6476	Ref.		Ref.		Ref.	
6476–7688	0·95	0·79, 1·14	1·00	0·83, 1·21	1·01	0·83, 1·22
7688–9676	0·84*	0·71, 0·98	0·94	0·79, 1·12	0·95	0·78, 1·16
≥9676	0·70*	0·61, 0·79	0·83*	0·70, 0·97	0·82*	0·67, 1·00
Portion size[c] (standard portion factor = 1)	0·78*	0·70, 0·87	0·94	0·80, 1·11	1·03	0·84, 1·27

WC, waist circumference; SEIFA, Socio-economic Indexes for Areas; TV, television; DQI, Diet Quality Index; Ref., reference category.
*Indicates a statistically significant result.
†Multivariate analysis adjusted for sex and age group.
‡Multivariate analysis adjusted for: variables marked 'a' – sex, age group, country of birth and Aborginal and Torres Strait Islander status; variables marked 'b' – everything listed under 'a' plus education, occupation, marital status, whether living in an Australian capital city; variables marked 'c' – everything listed under 'a' and 'b' plus physical activity, TV viewing, smoking status, diet quality, alcohol, energy intake and portion size.
§OR calculated per 1000 kJ/d.

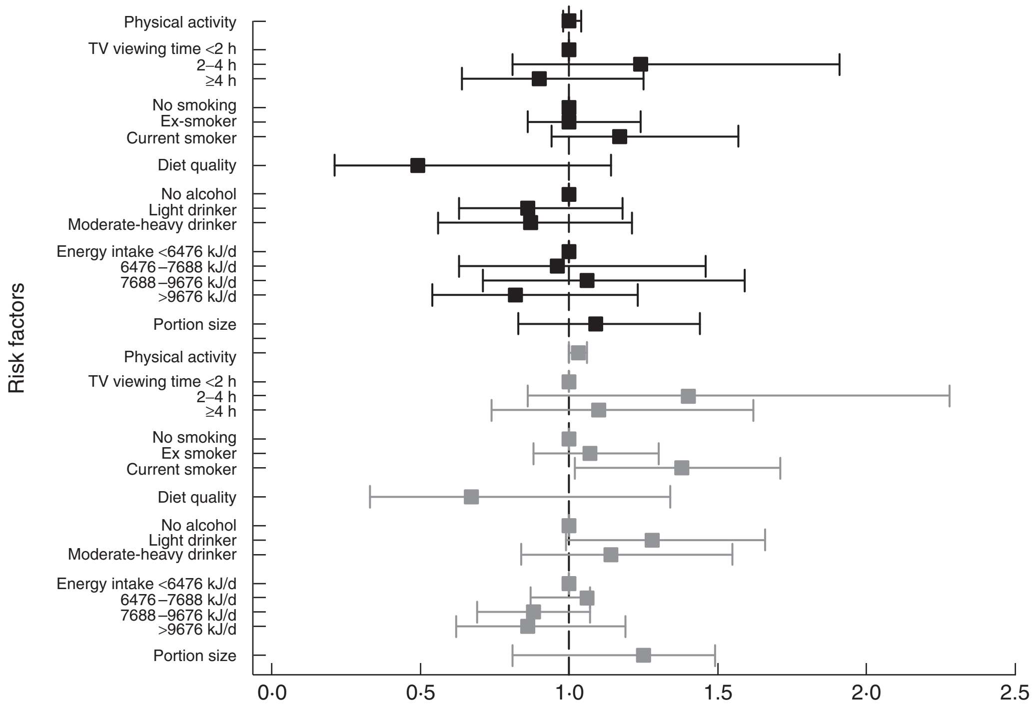

Fig. 1 Multivariate OR (95 % CI) of potential predictors of waist circumference gain in men (■) and women (■) (multivariate analysis adjusted for sex, age group, country of birth, Aborginal and Torres Strait Islander status, education, occupation, marital status, whether living in an Australian capital city, physical activity, television viewing, smoking status, diet quality, alcohol, energy intake and portion size). OR for energy intake was calculated per 1000 kJ/d

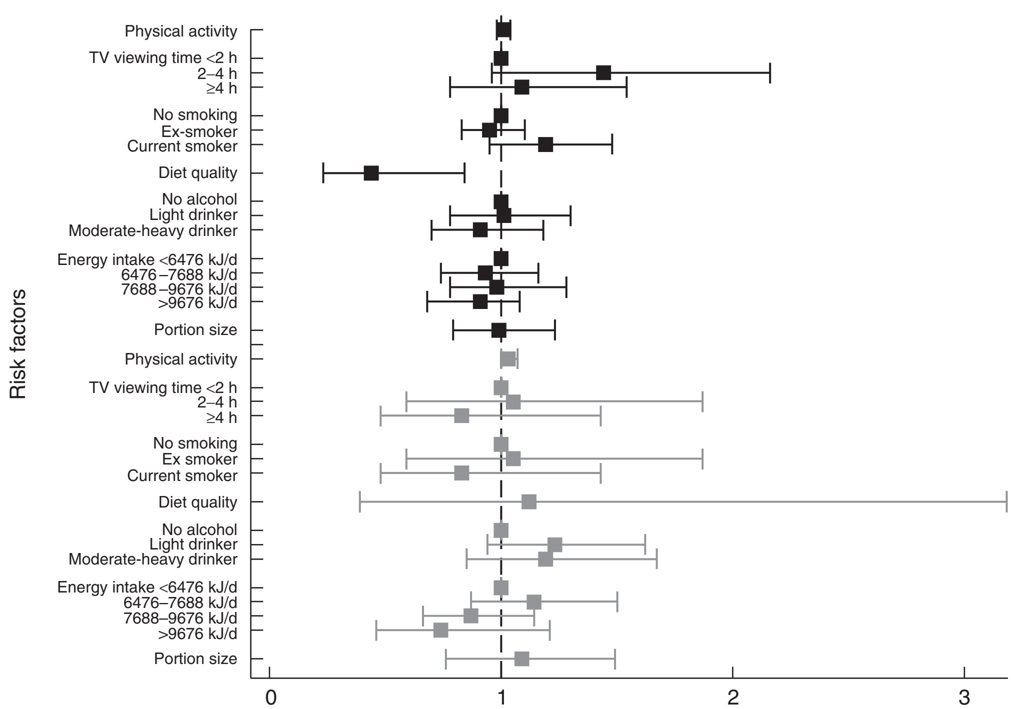

Fig. 2 Multivariate OR (95 % CI) of potential predictors of waist circumference gain in people aged 25–54 years (■) and ≥55 years (■) (multivariate analysis adjusted for sex, age group, country of birth, Aborginal and Torres Strait Islander status, education, occupation, marital status, whether living in an Australian capital city, physical activity, television viewing, smoking status, diet quality, alcohol, energy intake and portion size). OR for energy intake was calculated per 1000 kJ/d

Table 4 Multivariate† OR of potential predictors of WC gain in people of low-risk, increased-risk and substantially-increased-risk WC

	Multivariate† OR					
	Low-risk WC		Increased-risk WC		Substantially-increased-risk WC	
Variables	OR	95 % CI	OR	95 % CI	OR	95 % CI
Physical activity time (min/week)	1·00	0·99, 1·02	1·02	0·98, 1·05	1·00	0·97, 1·02
TV viewing time (h/d)						
<2	Ref.		Ref.		Ref.	
2–4	1·87*	1·17, 2·98	1·20	0·68, 2·11	0·68	0·36, 1·31
≥4	1·24	0·81, 1·91	1·47	0·92, 2·34	0·61*	0·38, 0·99
Smoking status						
Never smoker	Ref.		Ref.		Ref.	
Ex-smoker	1·05	0·85, 1·32	1·21	0·93, 1·57	1·13	0·85, 1·52
Current smoker	0·99	0·73, 1·35	1·48	0·91, 2·41	1·63*	1·07, 2·48
Diet quality (DQI/100) (mean, SE)	0·60	0·27, 1·34	1·12	0·38, 3·25	0·19*	0·06, 0·63
Alcohol						
Current non-drinkers	Ref.		Ref.		Ref.	
Light drinkers	1·08	0·82, 1·43	1·43	0·92, 2·24	0·84	0·59, 1·19
Moderate-heavy drinkers	0·97	0·68, 1·39	1·59	0·99, 2·54	0·78	0·54, 1·14
Energy intake (kJ/d)‡	0·97	0·93, 1·01	0·96	0·90, 1·01	0·99	0·94, 1·05
<6476	Ref.		Ref.		Ref.	
6476–7688	1·15	0·85, 1·55	0·84	0·56, 1·25	1·01	0·70, 1·45
7688–9676	1·02	0·76, 1·38	0·90	0·61, 1·32	0·89	0·62, 1·29
≥9676	0·95	0·75, 1·20	0·59*	0·38, 0·90	0·81	0·52, 1·27
Portion size (standard portion factor = 1)	1·23	0·90, 1·69	1·42	0·92, 2·19	0·97	0·66, 1·43

WC, waist circumference; TV, television; DQI, Diet Quality Index; Ref., reference category.
*Indicates a statistically significant result.
†Multivariate analysis adjusted for sex, age group, country of birth, Aborginal and Torres Strait Islander status, education, occupation, marital status, whether living in an Australian capital city, physical activity, TV viewing, smoking status, diet quality, alcohol, energy intake and portion size.
‡OR calculated per 1000 kJ/d.

of which we are aware, exploring predictors of an increase in WC, found low levels of physical activity and current smoking to be predictors of WC gain over a 3-year period in US women aged 42–52 years[5]. While we also found current smoking to be predictive of WC gain in our analysis, this was shown to be driven by people quitting over the study period. Current smoking in itself was not a predictor. Low physical activity levels did not feature as a predictor of WC gain in our analysis, as they did in many of the longitudinal studies. Cross-sectional studies have reported fairly consistent associations between behaviours considered to be either risk or protective factors for BMI/WC gain – such as TV viewing, physical activity, diet quality, fruit and vegetable consumption and portion size[20,27–29]. We found significant associations with diet quality – which also encapsulates fruit and vegetable consumption – and the suggestion of a greater likelihood of WC gain to be associated with greater portion size and some categories (generally not the highest) of increased TV viewing. Re-groupings of categories such as TV viewing did not substantially affect these results. With the exception of the group aged ≥55 years, for whom high levels of physical activity were associated with WC gain, we found no association between physical activity and WC gain. This may be due to the more sophisticated measurement of physical activity in the study by Sternfeld *et al.*[5] (which measured physical activity in various domains, including sports/exercise, household/caregiving and daily routine)[5]. The general lack of predictors in our study may be due to the period of follow-up (5 years), the study design, the definition of WC gain or the predictors being 'set' at an earlier stage in the life course.

Poor dietary quality in this context refers to a poor diet quality relative to national recommendations for adults. The index on which the measure is based has been found to appropriately explain variation in a wide range of food and nutrients thought to contribute to health, and is considered a practical means of evaluating the overall quality of diet in adults. No one component of the DQI contributes disproportionately more than any other and thus it is difficult to explain the dietary components or patterns explaining the observed trends[22]. The relationship between low energy intake and gain in WC is surprising, particularly considering the inclusion of physical activity levels as a confounder in the multivariate analysis.

There were some limitations to the study. The follow-up period of 5 years may be inappropriate for the identification of many predictors of WC gain. Five years may be too long, in that behaviours may have changed substantially over that length of time, limiting the relevance of the baseline behaviours. Similar findings of comparable (or shorter) periods revealed other predictors. The definitions of WC gain (≥5 % increase of baseline WC) and WC maintenance (change within 5 % of baseline WC) may affect the results. A change of 5 % in baseline WC is an arbitrary threshold for WC change; however, there is evidence in the literature to support its use. Stevens *et al.*[30] recommend that a change of ±3 % should be considered a weight gain/loss, and that a change of ±5 % is large enough to be considered clinically relevant. However, we did explore other groupings, such as a 5 % gain in WC *v.* the rest of the population (including people with WC gain, WC maintenance and WC loss), and a ≥2 % increase and change from 2 % in baseline WC (data not shown). The results were not substantially different when we explored these other groupings. We also analysed differences by absolute change in WC, and again the results did not differ substantially. We chose not to adjust for baseline WC in the multivariate analyses as such adjustment would likely result in spurious associations (although the analysis with this adjustment was generally not very different, data not shown)[31].

We have also presented the results by WC groupings, to explore whether the two comparator groups are highly similar – the people who maintained baseline WC having recently undergone WC gain themselves. If the results are affected by the maintainers having also gained WC recently, the difference between the two groups should be most obvious in the lowest WC category – the low-risk WC category. However, the lack of associations persisted, even in the low-risk WC group, for whom a recent WC gain in people who maintained baseline WC is unlikely. This suggests that the findings are not affected by the comparator group.

The potential selection bias in AusDiab is an important limitation to our study, due to the healthy volunteer bias and the 37 % and 61 % response rates to the first and second surveys, respectively. These low response rates and high loss to follow-up may mean that the proportion of people who underwent WC gain is not wholly reflective of the population incidence rates[16]. The low response rates could lead to either an under- or overestimation of weight gain[32]. However, an under-representation is most likely as non-response has been linked to having a sedentary lifestyle and lower socio-economic status (also associated with a higher body weight in developed countries)[33,34]. In addition, less than half of the cohort (*n* 5247) had both the baseline and follow-up measurements. Loss to follow-up in the present study was associated with higher BMI, lower levels of physical activity, higher prevalence of diabetes mellitus and a higher prevalence of smoking[35]. Although these factors, with the exception of smoking, are associated with weight gain, it is difficult to know how such a bias would affect predictors of WC gain. There may also be a greater self-report bias for levels of some behavioural factors in people of higher body weights, which may explain our finding of a greater odds of WC gain among people with a substantially-increased-risk WC in people who viewed <2 h/d of TV than in people who viewed ≥4 h/d.

Physical activity and TV viewing time were assessed over the previous week while the dietary assessment was carried out by a questionnaire that measures the habitual diet over 1 year. Ideally, the respective assessments would be consistent; however, physical activity and TV viewing time are relatively habitual and have both been shown to provide reliable and valid estimates of physical activity and TV viewing time in adults[18,27,36,37]. Furthermore, this combination of variables is commonly used[9,38,39].

The difference in the significant predictors in this analysis and those identified in cross-sectional analyses, and the many counter-intuitive results in this analysis, may be explained by life course epidemiology, which considers health and disease in adults to be influenced independently, cumulatively and interactively by various biological and social factors throughout life. Thus, an outcome in adulthood, such as weight gain, would be attributable to biological and social exposures operating during gestation, childhood, adolescence, young adulthood and later adult life[40], for which a factor such as adult TV viewing might be a marker. Thus, in this example, adult TV viewing and leisure-time PA might be cross-sectional markers of an accumulated poor lifestyle rather than a causative factor in adult life.

The suggestion that many factors found to be associated with high body weight in cross-sectional analyses are markers of accumulated poor lifestyles, but not in themselves strong predictors of future WC gain, has important implications. Rather than a narrow focus on 'reducing TV viewing' or 'reducing portion size', a broader focus on 'healthy lifestyles' may be more important – and one that begins at gestation/childhood and lasts lifelong.

In conclusion, in an Australian cohort of men and women aged ≥25 years, a significant proportion experienced a ≥5 % increase in baseline WC over a 5-year period. Poorer diet quality was found to be the key behavioural predictor of WC gain in this population. Many of the factors associated with higher WC in cross-sectional analyses were not predictive of a gain in WC. These findings highlight the need to understand better the causative role of lifestyle and health behaviours with regard to increasing WC over time.

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Australia Northern Territory, Eli Lilly Australia, Estate of the Late Edward Wilson, GlaxoSmithKline, Jack Brockhoff Foundation, Janssen-Cilag, Kidney Health Australia, Marian & FH Flack Trust, Menzies Research Institute, Merck Sharp & Dohme, Novartis Pharmaceuticals, Novo Nordisk Pharmaceuticals, Pfizer Pty Ltd, Pratt Foundation, Queensland Health, Roche Diagnostics Australia, Royal Prince Alfred Hospital, Sydney, Sanofi Aventis, Sanofi Synthelabo. The authors have no conflicts of interest to declare. H.L.W, D.J.M., J.J.M., C.S. and A.P. designed the study; H.L.W. analysed the data and wrote the article; H.L.W. and Z.A. collated the table of prior studies. All authors reviewed drafts of the manuscript. The authors thank A Forbes, R Bellomo, D Dunstan and R Freak-Poli for their comments regarding the design of the present study. Also, for the invaluable contribution to the setup and field activities of AusDiab, the authors are enormously grateful to A Allman, B Atkins, S Bennett, A Bonney, S Chadban, M de Courten, M Dalton, D Dunstan, T Dwyer, H Jahangir, D Jolley, D McCarty, A Meehan, N Meinig, S Murray, K O'Dea, K Polkinghorne, P Phillips, C Reid, A Stewart, R Tapp, H Taylor, T Whalen, F Wilson and P Zimmet.

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