Original Article

Dietary behaviours, weight loss attempts and change in waist circumference: 15-year longitudinal study in Australian adults

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Background and Objectives: Dietary behaviours are suitable as clearly identifiable targets of dietary counselling to prevent weight gain. We therefore investigated associations between dietary behaviours, weight loss attempts and waist circumference change. **Methods and Study Design:** Participants were a community-based sample population residing in Nambour, Australia, including 1,317 adults, aged 25-75 years at baseline. Waist circumference was measured in 1992 and 2007, and dietary behaviours data were derived concurrently from repeated self-completed short dietary questions. Multivariable models, stratified by sex, were adjusted for potential confounders. **Results:** In men, consumption of visible fat on meat and in women, weight loss attempts in the last 10 years were the most important predictors of waist circumference gain independent of socio-demographic and lifestyle characteristics and energy intake. Men who consumed most visible fat on meat had a 2.6 times larger yearly increase in waist circumference than men who tended to cut the fat off meat: 0.47 (95% CI 0.23, 0.72) vs 0.18 (95% CI 0.01, 0.34) cm/year, p=0.01. Women who reported that they were always trying to lose weight had a 2.7 times larger yearly increase in waist circumference than women who never tried to lose weight: 0.78 (0.54, 1.02) vs 0.29 (0.06, 0.52) cm/year, p=0.0001. Other dietary behaviours were not associated with change in waist circumference. **Conclusions:** Consumption of visible fat on meat by men and more frequent attempts to lose weight by women were main dietary behaviours associated with gain in abdominal adiposity in Australian adults.

Key Words: waist circumference change, dietary behaviours, weight loss attempts, longitudinal studies, abdominal obesity

INTRODUCTION

Abdominal obesity, independent of general obesity, is known to increase the risk of cardiometabolic disease, including heart disease, stroke, diabetes, hypertension, and some types of cancer.[1] Energy imbalance, as a consequence of low physical activity and/or high energy intake, is the core reason for development of abdominal obesity over time,[2] besides the role of some genetic factors.[3]

Diet as a modifiable determinant of general and abdominal obesity has been studied by considering intake of macronutrients[4,5] and food items,[6] or dietary patterns.[7-9] However, evidence on such associations with specific dietary behaviours, in particular in relation to abdominal obesity, is limited.[10] Specific dietary behaviours can serve as proxy indicators for a person’s general dietary pattern, and may affect the energy balance and thus the probability of developing abdominal obesity over time. Dietary behaviours are amenable to change and are suitable as clearly identifiable targets of dietary counselling. Thus knowledge of which dietary behaviours are associated with abdominal adiposity can be used readily in dietary advice and obesity prevention.

Adherence to a diet in order to lose weight is known to predict a subsequent gain in total body weight when assessed in studies with a medium-length follow-up time (2-6 years).[11-13] However, whether this association also applies to abdominal obesity and holds over the longer-term is not known. We therefore examined the long-term associations between dietary behaviours and weight loss attempts and change in waist circumference (WC) over a 15-year period by using repeated measurements of WC in a community-based sample of Australian adults. We hypothesized that unhealthy dietary behaviours as well as more frequent weight loss attempts would be associated with greater increase in WC in long-term follow-up.

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METHODS

Study population

We used dietary and anthropometric data collected as part of a community-based cohort study of Australian adults. The design, study population, baseline data collection and follow-up methods have previously been described in detail.[14] In brief, participants were 1,621 residents of the Nambour township, Queensland, who were originally randomly selected from the electoral roll (voting is compulsory in Australia) and participated in a skin cancer prevention trial (1992–1996) and were followed up until 2007. The study participants were aged 25-75 years at baseline in 1992.

WC was measured at a study clinic by trained staff in 1992 and 2007 and information on dietary behaviours were collected concurrently. Participants with available data on dietary behaviours were included in the present analyses if their WC was measured in either 1992 or 2007. While a total of 1,621 participants enrolled in the study in 1992, the analytical cohort for this study consisted of 1,317 individuals who contributed a total of 1,933 observations (one observation = one measurement of WC of one person at one time-point). The study protocol was approved by the Ethics Committee of the QIMR Berghofer Medical Research Institute. Written informed consent was obtained from all subjects/patients.

Waist circumference measurement

At the study clinic, participants were asked to remove most of their clothes and wear a light gown. They then stood straight with the abdomen relaxed, arms at the sides, feet together and their weight equally distributed over both legs. To perform the WC measurement, the midpoint between the lower edge of the lowest rib and the upper edge of the iliac crest (hip bone) was located by palpating, and marked. A flexible non-stretch fibreglass tape was placed horizontally at this marked midway level, about the level of the umbilicus, and held firmly so that it stayed in position without compressing the skin around the abdomen. The measurement was then read to the nearest millimetre. Two measurements per person were taken and a mean of the two measurements was considered as the final measurement.

Explanatory variables

A series of short questions about dietary behaviours were collected as part of a food frequency questionnaire (FFQ) in 1992 and 2007. The FFQ adapted from the US Nurses' Health Study which had been previously validated in our study population.[15] Estimates of energy and alcohol showed reasonable to good correlations when compared with weighed food records (Spearman correlation coefficient 0.45 and 0.85 respectively, $p<0.05$).[16]

The short dietary behaviour questions were related to: the number of teaspoons of sugar added to foods/drinks per day (none, ≤3, >3), consumption of visible fat on meat (does not eat meat, cuts the fat off, eats some of it, eats most of it), frequency of eating fried foods at home (never or <1/week, 1-3/week, 4-6/week, ≥1/day), frequency of eating fried takeaway foods (never, <1/week, 1-3/week), addition of butter or margarine to vegetables (yes/no), type of fat most often used for frying/roasting (none, vegetable oil, margarines, butter, other). Participants also reported their intentional weight loss attempts in the last 10 years (never, 1-4 times, ≥5 times, always, not reported).

Possible confounding variables

Details of socio-demographic and lifestyle factors were collected through self-completed questionnaires in 1992 and 2007. These variables were used in the present analyses to examine whether they confounded associations between dietary behaviours or weight loss attempts and WC change.

Participants were considered to have a medical condition if they answered 'yes' to the following question: 'Have you ever been told by a doctor/nurse that you have: glaucoma, gallstones, high cholesterol, high triglycerides, diabetes/high blood sugar, high blood pressure/hypertension, angina, heart attack, stroke, cancer?'. Smoking status was ascertained based on the timing and number of pack-years smoked, calculated from the frequency and duration of cigarettes smoked, for each period preceding each of the two examination years.

Recreational physical activity (used as an approximation of energy expenditure) was measured as weekly metabolic equivalents (MET-hours/week), as described elsewhere.[17] In brief, we used participants' reports on the frequency and duration (in hours and minutes) of three categories of exercise done for sport, recreation or fitness during the past 2 weeks, classified as walking, moderate and vigorous activities. Metabolic equivalent (MET) values, defined as the ratio of work metabolic rate to a standard resting metabolic rate of 1.0 (4.184 kJ)/kg/hour were assigned for walking (light activity), moderate activity, and vigorous activity (3, 5, and 9 respectively) according to the Compendium of Physical Activities,[18] and multiplied by the hours exercised at that intensity level per week, to obtain MET-hours/week for each activity level and all levels combined (total recreational activity). The reference category for each variable included individuals who reported no activity, i.e. zero hours or minutes. Active study participants were ranked into approximately equal thirds based on sex-specific cut-points.

Education comprised four attainment categories (grade 12 or less, technical/college diploma, trade/apprenticeship, bachelor or higher, other). For women, self-reported current use of Hormone Replacement Therapy (HRT; yes/no) and parity (nulliparous, 1 child, 2, 3, 4, 5-7 children) were considered in the analyses.

Baseline abdominal obesity was considered as one of the possible confounding variables. Therefore baseline WC was used as a categorical covariate in the analyses after applying WHO criteria for abdominal overweight and obesity: overweight: 94-101.9 cm for men, 80.0-87.9 cm women; obese: ≥102 cm for men, ≥88.0 cm for women.[19]

Energy intake (kJ/day) was calculated from the FFQ data. Alcohol consumption (g/day) was calculated from the FFQ data, and categorized based on national alcohol guidelines:[20] none, moderate (≤40 g/day men, ≤20 g/day women), and heavy (>40 g/day men, >20 g/day women).

Statistical analysis

The longitudinal associations between explanatory variables and WC change were assessed using linear regression applying generalised estimating equations (GEE).[21] WC was used as a continuous outcome variable, and change in WC per year in each category of covariates was calculated by including an interaction term between the variable and time (year of observation as a continuous variable).

Variables were included as time-dependent (changing over time) or time-independent (constant over time) variables. For time-dependent variables (all dietary behaviours, presence of a medical condition, physical activity level, alcohol consumption, smoking status, energy intake, and use of HRT in women), data from 1992 and 2007 were used. Age, categories of abdominal obesity at baseline, education (all in 1992), parity (in 2004), and weight loss attempts in the past 10 years (in 2007) were considered as time-independent variables.

The analyses were carried out in two steps: (a) univariate analyses for each dieting and dietary behaviour and WC change, and (b) multivariable-adjusted analyses to identify which dieting and dietary behaviours was independently related to WC change over time. In the multivariable model, initial adjustments (model 1) were made for age and baseline abdominal obesity. Further adjustments (model 2) were then made for education, presence of a medical condition, physical activity, smoking status, alcohol consumption, and total energy intake. The adjustment included both the main effect and the interaction term with time for the variable. Age (centred on the mean) and its squared value were used in the multivariable models when adjusting for this variable. Also, we investigated whether the associations between dietary behaviors and WC change were modified by sex by testing multiplicative interaction terms of each of these variables and sex.

A p-value for the overall association between a covariate and WC change was derived from the likelihood ratio test for interaction of each covariate by time. A p-value for subgroup comparisons within each covariate was derived from a Wald-test based on parameter estimates and standard errors from the GEE model. To examine the pattern of missingness due to persons dropping out of the study, and to check whether the assumption of missing at random could be made, we compared the characteristics of the participants included in the analyses with those excluded using multiple logistic regressions applying the GEE approach. All the tests were two-sided and values of $p<0.05$ were considered statistically significant. All analyses were carried out using SAS statistical package version 9.3 (SAS Institute, Cary, NC).

RESULTS

Of the 1,317 study participants, 701 (53%) individuals had one WC measurement and 616 (47%) had two WC measurements. The cohort consisted of 568 (43%) men and 749 (57%) women yielding a total of 1,221 observations in 1992, and 712 in 2007. At baseline, mean (SD) age was 49.0 (12.6) years and mean (SD) body mass index (BMI) was 26.1 (4.2) kg/m^2; 28% of the participants were abdominally overweight and 27% were abdominally obese.

Study participants who were excluded from the analysis (n=304) due to missing data on WC were more likely to be in the youngest (24-35 years) or oldest (≥65 years) age categories (p=0.02) (data not shown). Levels of education and physical activity, presence of a medical condition, and total energy intake were not different between these two groups.

Average gain in WC was 0.20 (±SE: 0.02) cm/year or 3.0 (±SE: 0.3) cm in total in this study population over 15 years of follow-up; 0.11 (±SE: 0.03) cm/year or 1.7 (±SE: 0.45) cm in total for men and 0.25 (±SE: 0.03) cm/year or 3.8 (±SE: 0.45) cm in total for women (women vs. men p=0.004).

The analyses were stratified by sex because our modelling showed evidence of significant interaction between sex and each of the dietary and dieting behaviours (all $p<0.01$). In men there was a significant positive relationship between consumption of visible fat on meat and WC change over time (p=0.04) (Table 1). In univariate analyses as well as after full confounder adjustment (model 2), men who ate most of the fat on meat had more WC gain compared with men who removed the fat from meat: 0.47 (95% CI 0.23, 0.72) cm/year vs 0.18 (95% CI 0.01, 0.34) cm/year. The frequency of eating fried food at home did not have a clear overall association with change in WC in men. However, sub-group comparisons in the first multivariable model indicated that men who ate fried foods more than once per day, had a greater WC gain over time than those who never ate fried food at home or ate such foods less than once per week (p=0.006). However, this association was no longer statistically significant in the fully adjusted multivariable model. None of the other investigated dietary or dieting behaviours was associated with WC change in men.

In women the frequency of intentional attempts to lose weight in the previous 10 years was associated with WC change (p=0.0001 after multivariable adjustment; Table 2), such that women who always tried to lose weight had a substantially larger average increase in WC compared with women who never tried to lose weight, 0.78 (95% CI 0.54, 1.02) cm/year vs 0.29 (95% CI 0.06, 0.52) cm/year). None of the other examined variables were associated with WC change in women.

DISCUSSION

Findings from this 15-year longitudinal study suggest that few dietary behaviours have a clear association with WC gain over time. Consumption of visible fat on meat by men and frequent attempts to lose weight by women were each associated with more than 2.5 times greater increases in WC per year. None of the other factors investigated were related to WC change over time.

Our study is one of few examining the association between dietary behaviours and WC change over a long follow-up period. In relation to the consumption of fat on meat, to the best of our knowledge there is no previous evidence on its association with WC change with which to compare our results. However, our findings agree with a study in younger Spanish adults, in which removing fat from meat was associated with lower gains in total body weight after 4.5 years of follow-up.[10]

We studied these dietary behaviours because they can

Table 1. Dieting and dietary behaviours and change in waist circumference (WC) in men (n=829 study observations across n=568 individuals)[†]

Correlates	Number of observations (%)	Univariate Model WC change (cm/year) Mean	95% CI	*p*-value[¶]	*p*-value[††]	Multivariable Model (1)[‡] WC change (cm/year) Mean	95% CI	*p*-value[¶]	*p*-value[††]	Multivariable Model (2)[§] WC change (cm/year) Mean	95% CI	*p*-value[¶]	*p*-value[††]
Number of teaspoons of sugar/day													
None	219 (27)	0.08	-0.03, 0.19	Reference	0.7	0.10	-0.01, 0.23	Reference	0.7	0.25	0.06, 0.43	Reference	0.9
≤3	262 (33)	0.12	0.02, 0.23	0.3		0.13	0.02, 0.24	0.7		0.22	0.07, 0.38	0.8	
>3	313 (40)	0.15	0.04, 0.26	0.9		0.17	0.05, 0.30	0.4		0.25	0.07, 0.43	1.0	
Consumption of visible fat on meat													
Does not eat meat	6 (1)	-0.24	-0.50, 0.03	0.03	0.04	-0.40	-0.57, -0.24	0.0001	0.03	0.13	-0.40, 0.16	0.05	0.04
Cuts it off	493 (62)	0.08	0.00, 0.15	Reference		0.10	0.01, 0.19	Reference		0.18	0.01, 0.34	Reference	
Eats some of it	182 (23)	0.13	-0.01, 0.28	0.5		0.21	0.08, 0.34	0.1		0.28	0.11, 0.45	0.2	
Eats most of it	109 (14)	0.38	0.20, 0.56	0.003		0.39	0.18, 0.61	0.009		0.47	0.23, 0.72	0.01	
Frequency of eating fried food at home													
Never or <1/week	184 (23)	0.04	-0.08, 0.16	Reference	0.2	0.09	-0.04, 0.21	Reference	0.09	0.16	-0.03, 0.34	Reference	0.4
1-3/week	360 (46)	0.10	0.01, 0.19	0.4		0.13	0.03, 0.22	0.6		0.23	0.07, 0.39	0.3	
4-6/week	185 (23)	0.10	-0.09, 0.29	0.6		0.09	-0.10, 0.27	1.0		0.14	-0.12, 0.39	0.8	
≥1/day	62 (8)	0.44	0.18, 0.70	0.009		0.45	0.21, 0.68	0.006		0.43	0.15, 0.72	0.08	
Frequency of eating fried takeaway foods													
Never	67 (8)	0.03	-0.33, 0.39	Reference	0.3	0.16	-0.08, 0.41	Reference	0.2	0.31	0.07, 0.57	Reference	0.3
<1/week	581 (73)	0.11	0.04, 0.19	0.7		0.12	0.03, 0.21	0.7		0.20	0.04, 0.36	0.4	
1-3/week	146 (19)	0.27	0.10, 0.45	0.4		0.29	0.11, 0.46	0.4		0.35	0.13, 0.57	0.8	
Addition of butter/margarine to vegetables													
No	459 (58)	0.15	0.07, 0.22	Reference	0.3	0.17	0.08, 0.25	Reference	0.6	0.28	0.12, 0.43	Reference	0.4
Yes	336 (42)	0.07	-0.05, 0.19	0.3		0.13	0.00, 0.26	0.6		0.22	0.05, 0.39	0.4	
Type of fat used for frying/roasting													
None	66 (8)	0.18	-0.12, 0.47	Reference	0.8	0. 22	-0.10, 0.54	Reference	0.9	0.39	0.07, 0.70	Reference	0.5
Vegetable oil	361 (46)	0.05	-0.04, 0.14	0.4		0.11	0.01, 0.20	0.5		0.18	0.03, 0.33	0.1	
Margarines	101 (13)	0.11	-0.18, 0.39	0.7		0.12	-0.10, 0.33	0.6		0.29	0.01, 0.56	0.2	
Butter	24 (3)	-0.06	-0.96, 0.85	0.6		-0.14	-1.01, 0.72	0.4		-0.01	-0.82, 0.81	0.4	
Other	239 (30)	0.13	0.02, 0.25	0.8		0.15	0.04, 0.26	0.7		0.27	0.12, 0.41	0.4	
Weight lost attempts in the last 10 years													
Never	183 (22)	0.19	0.08, 0.29	Reference	0.4	0.18	0.06, 0.30	Reference	0.4	0.23	0.04, 0.41	Reference	0.6
1-4 times	141 (17)	0.10	-0.01, 0.20	0.2		0.10	-0.03, 0.22	0.3		0.20	0.01, 0.39	0.7	
≥5 times	54 (7)	0.15	-0.04, 0.34	0.8		0.15	-0.07, 0.37	0.8		0.23	-0.02, 0.49	1.0	
Always trying	39 (5)	0.21	0.05, 0.38	0.8		0.29	0.09, 0.49	0.4		0.38	0.17, 0.60	0.1	
Unknown[‡‡]	412 (49)	0.05	-0.08, 0.17	0.08		0.09	-0.04, 0.23	0.3		0.20	0.03, 0.37	0.7	

[†]Values are means ± 95% CI, derived from the interaction between covariates and time using generalized estimating equation and data collected in 1992 and 2007.
[‡]Adjusted for age and baseline abdominal obesity.
[§]Adjusted for age, baseline abdominal obesity, education, presence of a medical condition, physical activity, smoking status, alcohol consumption, and total energy intake.
[¶]Comparison between categories. *P*-values from Wald test based on parameter estimate and standard error from generalised model.
[††]*p*-value from likelihood ratio test for interaction of covariate by time.
[‡‡]This variable was assessed in 2007 only.

Table 2. Dieting and dietary and change in waist circumference (WC) in women (n=1,087 study observations across n=733 individuals)[†]

Correlates	Number of observations (%)	Univariate Model				Multivariable Model (1)[‡]				Multivariable Model (2)[§]			
		WC change (cm/year)		*p*-value[¶]	*p*-value[††]	WC change (cm/year)		*p*-value[¶]	*p*-value[††]	WC change (cm/year)		*p*-value[¶]	*p*-value[††]
		Mean	95% CI			Mean	95% CI			Mean	95% CI		
Number of teaspoons of sugar/day													
None	496 (47)	0.21	0.12, 0.30	Reference	0.7	0.33	0.22, 0.43	Reference	0.9	0.39	0.18, 0.59	Reference	0.9
≤3	344 (32)	0.22	0.11, 0.34	0.9		0.30	0.17, 0.44	0.7		0.41	0.19, 0.62	0.8	
>3	219 (21)	0.28	0.14, 0.41	0.4		0.33	0.18, 0.47	1.0		0.39	0.17, 0.60	1.0	
Consumption of visible fat on meat													
Does not eat meat	33 (3)	0.38	0.01, 0.75	0.4	0.3	0.41	0.05, 0.78	0.6	0.7	0.47	-0.05, 1.00	0.7	0.6
Cuts it off	778 (74)	0.22	0.15, 0.29	Reference		0.31	0.22, 0.40	Reference		0.38	0.19, 0.57	Reference	
Eats some of it	188 (18)	0.20	0.03, 0.37	0.8		0.33	0.17, 0.50	0.8		0.45	0.21, 0.69	0.6	
Eats most of it	52 (5)	0.56	0.23, 0.90	0.05		0.51	0.13, 0.88	0.3		0.59	0.25, 0.93	0.2	
How often eat fried food at home													
Never or <1/week	320 (30)	0.21	0.07, 0.34	Reference	0.4	0.31	0.19, 44.0	Reference	0.3	0.40	0.19, 0.61	Reference	0.5
1-3/week	476 (45)	0.24	0.14, 0.34	0.7		0.33	0.20, 0.46	0.8		0.41	0.21, 0.61	0.9	
4-6/week	218 (21)	0.32	0.17, 0.46	0.3		0.37	0.23, 0.50	0.6		0.40	0.17, 0.63	1.0	
≥1/day	44 (4)	-0.05	-0.41, 0.32	0.2		0.05	-0.24, 0.34	0.09		0.15	-0.20, 0.51	0.1	
How often eat fried takeaway foods													
Never	101 (10)	0.22	-0.17, 0.61	Reference	0.9	0.29	0.08, 0.50	Reference	0.9	0.56	0.21, 0.92	Reference	0.6
<1/week	850 (80)	0.24	0.17, 0.31	0.9		0.33	0.24, 0.43	0.7		0.41	0.22, 0.63	0.4	
1-3/week	108 (10)	0.28	0.06, 0.51	0.8		0.31	0.09, 0.54	0.9		0.38	0.12, 0.63	0.3	
Addition of butter/margarine to vegetables													
No	362 (34)	0.22	0.14, 0.30	Reference	0.6	0.32	0.23, 0.42	Reference	0.7	0.42	0.24, 0.61	Reference	1.0
Yes	699 (66)	0.26	0.14, 0.38	0.6		0.30	0.17, 0.43	0.7		0.42	0.20, 0.63	1.0	
Type of fat used for frying/roasting													
None	88 (8)	0.13	-0.11, 0.37	Reference	0.6	0.23	0.02, 0.44	Reference	0.6	0.40	0.13, 0.66	Reference	0.2
Vegetable oil	486 (46)	0.23	0.12, 0.33	0.5		0.27	0.16, 0.38	0.7		0.34	0.14, 0.55	0.6	
Margarines	103 (10)	0.03	-0.24, 0.30	0.6		0.09	-0.23, 0.41	0.4		0.09	-0.32, 0.51	0.1	
Butter	20 (2)	0.18	-0.22, 0.57	0.8		0.30	-0.02, 0.62	0.7		0.66	0.22, 1.10	0.3	
Other	361 (34)	0.27	0.15, 0.40	0.3		0.35	0.23, 0.48	0.3		0.47	0.13, 0.66	0.6	
Weight lost attempts in the last 10 years													
Never	142 (13)	0.17	0.04, 0.31	Reference	0.0003	0.21	0.05, 0.36	Reference	0.002	0.29	0.06, 0.52	Reference	0.0001
1-4 times	210 (19)	0.34	0.22, 0.46	0.07		0.36	0.22, 0.49	0.09		0.52	0.31, 0.72	0.02	
≥5 times	131 (12)	0.25	0.11, 0.38	0.5		0.26	0.12, 0.40	0.6		0.42	0.22, 0.63	0.2	
Always trying	132 (12)	0.49	0.33, 0.66	0.004		0.57	0.40, 0.73	0.0005		0.78	0.54, 1.02	<0.0001	
Unknown[‡‡]	489 (44)	0.06	-0.05, 0.17	0.2		0.17	0.04, 0.30	0.7		0.31	0.11, 0.51	0.9	

[†]Values are means ± 95% CI, derived from the interaction between covariates and time using generalised estimating equation and data collected in 1992 and 2007.
[‡]Adjusted for age and baseline abdominal obesity.
[§]Adjusted for age, baseline abdominal obesity, education, presence of a medical condition, physical activity, smoking status, alcohol consumption, total energy intake, use of hormone replacement therapy, and parity.
[¶]Comparison between categories. *P*-values come from Wald test based on parameter estimate and standard error from generalised estimating equations model.
[††]*p*-value from likelihood ratio test for interaction of covariate by time.
[‡‡]This variable was measured in 2007 only

serve as proxy indicators for a general dietary pattern, or for intake of specific nutrients.[22] This was confirmed in our data, which showed that mean daily fat intake was 92 g for men who reported eating most of the fat on meat, compared to 82 g in men who usually cut the fat from meat (p<0.05, detailed data not shown). Intakes of saturated and trans-fatty acid are generally more closely associated with increases in body weight gain and abdominal obesity than total fat intake.[23,24] However, neither the type of fat used for frying/roasting, nor the addition of butter/margarine to vegetables was associated with WC change over time in our study.

Further analyses of our data showed that men who consumed the most fat on meat tended to show a clustering of unhealthy behaviours. That is, men who were most likely to eat the visible fat on meat were more likely to consume fried foods as takeaway meals, to have a high alcohol intake, and to add butter or margarine to vegetables. Furthermore, these men were less likely to have achieved a bachelor or a higher degree (all p<0.05, detailed data not shown). Such clustering of unhealthy behaviours and social patterning has also been shown in other studies.[25,26]

We found no association between consumption of fried takeaway foods and WC change, in contrast to some other investigations. In a 2-year follow-up analysis of the Baltimore Longitudinal Study of Aging, a diet high in fast food, as well as red and processed meat and soft drinks was associated with greater increases in WC and BMI.[7] Other studies from Australia[27] and elsewhere [22,28-30] have also generally reported a positive association between fried takeaway or fast foods and gain in weight or BMI. The lack of an association in our study may be due to the relatively low average frequency of fried takeaway food consumption in our study population compared with that in other studies. Only 19% of men and 10% of women in our study consumed takeaway fried foods more than once per week, which is well below the average frequency reported in other studies: 68% in a study of young Australian women,[27] and 50% or more in some American studies.[28,31] Interestingly, also in a cohort study of a Mediterranean population, 76% of the participants consumed fried foods as takeaway or at home twice or more per week.[22] The much lower frequency of consumption of fried take-away foods by our study participants compared with these other international studies is probably at least partly due to the relatively older age (average 49 years at base-line) of our study population. Furthermore, except for one study,[28] our follow-up period (15 years) was substantially longer than that of other studies (generally 2-4 years)[27,29,30] which may also explain some the discrepancy in findings.

In this study none of the dietary behaviours was related to WC change in women. Similarly, in our previous analyses we found that diet quality was not related to changes in BMI and WC in women in this study population.[32] This is not an uncommon finding in women—other studies on the association between dietary patterns[8,33] or consumption of food items,[6] and change in anthropometric measures in women have also shown mixed results. It is unclear why no such associations were seen in women. One possible explanation is that of reverse causality through overweight individuals adopting a healthier diet to manage their weight,[34] but there is no particular reason why this would have affected women more than men. In women, frequent attempts to lose weight in the previous 10 years were associated with substantially larger increases in WC, similar to such an association with weight gain in studies with a medium-term follow-ups.[11-13,35] Dieting to achieve weight loss is generally more common among women than men.[36] In 2007, 77% of women in our study reported that they had tried to lose weight at least once over the past 10 years compared with 56% of men. Dieting may be related to compensatory overeating and therefore result in cycles of dieting and weight gain,[37,38] which may have applied to the women in our study.

Further analysis of our data showed that this group of women, who constantly tried to lose weight, were more likely to be in the middle age group (45-54 years), to have a professional occupation, a medical condition, and fewer children (data not shown). Recreational physical activity was not related to attempts to lose weight in women. The menopausal transition is associated with an increase in intra-abdominal fat independent of total adiposity.[39] Taken together, our findings indicated that professional women who were in their middle ages, especially those who repeatedly tried to lose weight, were at high risk of developing abdominal obesity, and could be targeted in prevention efforts.

This study has several strengths. This is one of very few investigations to examine the association between concurrent changes in dietary behaviours and longitudinal WC change, while considering an extensive range of socio-demographic and life-style related confounding variables. We applied a suitable statistical technique for analysing longitudinal data, GEE, allowing for the dependence between repeated measures and it is robust against heterogeneity of the variance of the outcome in different categories of explanatory variables. This model allows for the dependence between repeated measures while it accounts for the problem relating to missing data in longitudinal analysis.[40] Only measured WC data was used, thus avoiding the biases associated with self-reported anthropometric data. This study was embedded in a longitudinal study of skin cancer; therefore anthropometric assessment was not a primary reason for participation in the study, thereby avoiding participation bias in the present analyses. Compared with those included in the analysis, participants who were excluded due to missing data were more likely to be in the youngest or oldest age categories. However all our analyses were adjusted for age and we believe that missing data are not a major limitation in our study. It should be noted that the sample size was chosen for the original skin cancer study. However, our statistically significant findings show that there was enough statistical power to detect difference in effect size in different categories of dietary behaviours.

It is important, however, to interpret these results in the light of some limitations. Although the associations were adjusted for a large number of covariates, there could be some residual confounding that may have affected the observed associations, or the lack thereof. Answers to the dietary behaviour questions might have been affected by social desirability, and we were not able to validate the answers given to these dietary behaviour questions. In addition, in self-reported dietary assessments, women tend to be more prone to social desirability bias than men, especially when reporting dietary behaviours relating to fat intake.[41] This may have affected the conflicting results between men and women in this study. For example, 37% of men reported that they had consumed some or most of the visible fat on meat while only 23% of women had reported to do so. In general, self-reported dietary intake is prone to inherent measurement error,[42] which may also have affected our results. We adjusted all analyses for energy expenditure by using a summary measure derived from recreational physical activity data, but this approximate measure may have caused incomplete confounding adjustment for energy expenditure. Furthermore, the relative influence of the dietary behaviours investigated may have been small compared with the influence of advancing age on increases in WC and abdominal obesity,[43] although patterns of associations were very similar in unadjusted univariate analyses compared to adjusted analyses. While this study is based on repeated observations within the same person at baseline and 15 years later, it is unknown what their dietary behaviour were during the intervening period. Finally, caution is needed in interpretation of the findings which come from subgroup analyses because due to the large number of comparisons some of these associations may have occurred by chance.

Conclusions

Our study showed that average WC increased substantially over a 15-year period in Australian men and women. It also showed that consumption of visible fat on meat in men and frequency of weight loss attempts in women were characteristics that helped to identify persons at risk of abdominal obesity. Although the actual differences in WC gain between different dietary behavior groups were small, there is evidence that such differences can be of clinical significance.[44] With the growing awareness of the negative health consequences of abdominal obesity, these findings provide further support to efforts that aim to reduce the burden of this increasing public health problem. However, more investigation is needed to explain whether inconsistent findings between men and women are due to methodological limitations or whether the biological effects of dietary behaviours are truly different between the sexes.

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AUTHOR DISCLOSURES

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