Changes in the rates of weight and waist circumference gain in Australian adults over time

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Data sharing

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Authorship statement

AP conceived of the article, executed the analysis and writing of the article and is guarantor for the article. JS, DM and KB contributed to the ideas included within and writing of the article, and provision of data. PZ contributed to the writing of the article and provision of data.

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Article summary

Article focus

- We aimed to assess for the first time in a single cohort whether annual change in weight and waist circumference has changed in recent time periods.

Key messages

- Between 2004/5–2011/2, Australian adults in this national cohort study continued to gain weight, but more slowly than 1999/2000–2004/5.
- In contrast waist circumference gain was greater in the most recent period. Important differences were observed according to area-level disadvantage.
- While some obesity prevention strategies may be working, they do not appear to be affecting those in more disadvantaged areas.

Strengths and limitations

- Reliably measured data in a single nationally representative cohort in recent time periods
- Selection and response bias may limit the generalisability of the results to the broader Australian population

ABSTRACT

Objective: To assess for the first time in a single cohort whether annual weight and waist circumference (WC) change has varied over time.

Design: Longitudinal cohort study with three surveys, 1 – 1999/2000; 2 – 2004/2005; 3 – 2011/2012. Generalized linear mixed models with random effects were used to compare annual weight and WC change between surveys 1 and 2 (Period 1) with that between surveys 2 and 3 (Period 2). Models were adjusted for age, sex, education status, area-level disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

Setting: The Australian Diabetes, Obesity and Lifestyle study (AusDiab) - a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years, recruited in 1999 -2000.

Participants: 3,351 Australian adults who attended each of three surveys and had complete measures of weight, WC and covariates at each survey.

Primary outcome measures: Weight and WC were measured according to standard protocols at each survey.

Results: Mean weight and WC increased in both Periods. Annual weight gain in Period 2 was 0.11 kg/year (95% CI 0.06–0.15) less than in Period 1. Improvement in annual weight gain between the two periods was not seen for those with greatest area-level disadvantage, or in men over the age of 55. In contrast, the annual WC increase in Period 2 was greater than in Period 1 (0.07 cm/year, 95% CI 0.01–0.12). In those with least area-level disadvantage only, annual WC gain was less in Period 2 than Period 1.

Conclusions: Between 2004/5–2011/2, Australian adults in a national study continued to gain weight, but more slowly than 1999/2000–2004/5. While some obesity prevention strategies

may be working, they do not appear to be affecting WC, older men or those in more disadvantaged groups.

Obesity in adults has increased rapidly over the past few decades, leading to prevalence of over one quarter in many developed countries. There is growing acceptance that strong preventive measures are required to stem the increasing prevalence, with a variety of approaches implemented, ranging from social marketing through whole of community interventions to regulatory strategies. However, it is difficult to evaluate whether elements of the approach to date have had a beneficial effect.

There have been some suggestions that obesity prevention interventions in children have had a positive effect, due to the observation that the prevalence of obesity is no longer increasing at the same rate. A recent review of 52 studies, from 25 countries, comparing obesity prevalence at two time points since 1999 [1] concluded that in more developed nations a likely slowing of the rate of increase in obesity prevalence was occurring in children, with a possible turning point around 2000. However, trends in adults generally appeared to be continuing to increase. Since this review, an analysis of US adults through the repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that time period in non-Hispanic white and Hispanic women, but continued increases in men and non-Hispanic black and Mexican American women [2]. In Australia, the latest reported data suggests a continued increase in obesity prevalence in adults to 2012 [3]. However, prevalence data is driven by a range of factors, including migration, mortality and response bias. To determine whether the degree of weight gain in the population has slowed over time, a comparison of the rates of weight change is required.

We aimed to analyse whether the degree of change in weight and waist circumference (WC) over time differed in a single cohort of adults, comparing weight and WC change in the same individuals between two consecutive time periods. We used the national Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [4], and compared annual change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

METHODS

Setting and Participants

The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years, recruited in 1999 -2000 (AusDiab1). Methods and response rates have been described previously[4]. Five-year follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3, respectively. For this analysis we excluded participants with missing data on weight or WC at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a final sample size of 3,351. Ethics approval was obtained from the International Diabetes Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented to participate in the study.

All study assessments followed a similar protocol. Data were collected by interviewer-administered questionnaires on medical history, lifestyle and health behaviour. Data on education, country of birth, smoking and physical activity and television viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was ascertained by asking if participants had been told by a doctor or nurse that they had angina, myocardial infarction, or stroke.

Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked tobacco daily) combined.

Education level was ascertained by asking the question "Which of these describes the highest qualification you have received?" Education was categorised as secondary only (comprising those with a secondary school qualification), diploma (comprising nursing or teaching qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor degree, post-graduate diploma or masters degree/doctorate)[5].

Area-level disadvantage was estimated using the Index of Relative Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was developed by the Australian Bureau of Statistics, to create a summary measure from a group of 20 variables (related to education, income, employment, family composition, housing benefits, car ownership, ethnicity, English language proficiency, residential overcrowding) displaying dimensions of social disadvantage [6]. The index is constructed so that high values reflect areas with high socio-economic status (relative advantage) and low values reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage were calculated amongst the final study sample.

Physical activity was measured via an interviewer-administered Active Australia questionnaire, which considered participation in predominantly leisure-time physical activities (including walking for transport) during the previous week [7]. Total physical activity time was calculated as the sum of the time spent walking (if continuous and for ≥10 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-intensity physical activity [8].

Self-reported television viewing time was calculated as the total time spent watching television or videos in the previous week, and is considered a reliable and valid estimate of television viewing time among adults [9].

Average daily energy intake was assessed using a self-administered validated food frequency questionnaire (FFQ) [10], which included 74 items (with 10 frequency options), with additional questions on food habits, portion size and consumption of alcoholic beverages. In AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential measurement error, manual blood pressure measurements were adjusted as previously described [Briganti, Shaw et al. 2003]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine. Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus Optical, Tokyo, Japan) at a central laboratory [11].

Classification of diabetes status has been described elsewhere [11]. Briefly, participants were classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and were either taking hypoglycaemic medication or had fasting plasma glucose (FPG) ≥7.0mmol/L or a 2-hour plasma glucose (PG)≥ 11.1mmol/L. Participants not reporting diabetes but with FPG≥7.0mmol/L or 2-hour PG≥ 11.1mmol/L were classified as having 'newly diagnosed diabetes'.

Outcomes

Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm. Weight was measured without shoes, excess clothing, and items in pockets by a single measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior to each set of measurements. BMI was obtained from the calculation of weight (kg) divided by height (m^2). Annual weight change was calculated as the difference in weight between AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time between the two consecutive surveys.

Waist circumference was measured twice, halfway between the lower border of the ribs and the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the mean of the two closest measurements was calculated. Annual WC change was calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by the follow-up time between the two consecutive surveys.

Statistical analysis

Baseline characteristics (means and proportions at AusDiab1) were compared between AusDiab participants with and without complete measures at AusDiab 1, 2 and 3. Characteristics of the included population were also compared in 2000 and 2005, representing the two baseline surveys for the two weight change periods.

The difference in annual weight and WC change in Period 1 (2000 to 2005), compared to Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear mixed models with random effects were used to analyse the association between study period on annual weight or WC change. This model includes random effects associated with both the cluster and the units of analysis (participants) to take the clustered structure of the data into account and to allow the residuals associated with the longitudinal measures on the same unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model 1), additionally adjusting for smoking, education, area level disadvantage and country of birth (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4). Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2 for change in Period 2. The association between study period and annual weight and WC change was also analysed across sub-groups and interaction terms between study period with age or sex were analysed.

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80.

All analyses were performed in STATA (version 11.0), with statistical significance set at the 5% level.

RESULTS

The population with complete measures was similar to the total AusDiab cohort with respect to sex and weight, but was younger, with higher educational attainment, and a higher prevalence of never smoking (Table 1). The population with complete measures also had a lower prevalence of chronic disease. There was no appreciable difference between the two groups for weight change in Period 1 after adjustment for differences in age and sex.

(Table 1 here)

Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to being five years older, the population had a higher prevalence of diabetes (predominantly type 2). In both periods the average change in weight and WC was a gain. In Period 2, a smaller proportion of the population gained weight and annual weight gain was less, at 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser weight change across the entire distribution of weight change in Period 2, with minimal difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile of weight change (Appendix Figure 1A). For WC, there was no difference in the crude annual change between the two periods (Table 2). In contrast to weight change, this resulted from both a smaller gain in those whose WC increased and a smaller loss in those whose WC decreased (Appendix Figure 1B). The correlation between annual weight change and annual WC change was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

(Table 2 here)

Comparison of the crude annual weight change for matching 10-year age-groups in Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups, although these differences were only significant for men aged 35–44, and women 45–54 and 65–74

(Appendix Table 1). Comparison of the crude annual WC change for matching age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64; Appendix Table 1).

The difference in annual weight and WC change in Period 2, compared to Period 1, was assessed using linear regression analysis (Table 3A). In Period 2, annual weight gain was 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after further adjustment for smoking status, education status, ethnicity, area-level disadvantage, baseline BMI and diabetes status (Table 3A), nor after adjustment for TV time, exercise time and energy intake (results not shown).

Annual weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 3A), with suggestions of a greater difference over time in women, and those aged under 55 years (although no interaction tests on these factors were significant). Annual weight gain in Period 2 was non-significantly less than in Period 1 for those with high educational attainment (borderline significant), obesity, and those from a non-English speaking background. No difference in annual weight gain between the two periods was observed for those in the tertile of greatest area-level disadvantage, nor for current smokers.

In Period 2, annual WC gain was 0.07 cm/year more than in Period 1 (Table 3B). This did not alter substantially after further adjustment for smoking status, education status, area-level disadvantage, ethnicity, baseline BMI and diabetes status (Table 3B), nor after adjustment for TV time, exercise time and energy intake (results not shown).

In stratified analyses no difference in annual WC gain between the two periods was observed for women, those aged<55 years, those in the highest education group, those with normal weight nor ex-smokers. Annual WC gain was less in Period 2 than Period 1 for those in the tertile of least area-level disadvantage (-0.14cm/year 95%CI -.05, -0.23).

(Table 3 here)

For both weight and WC, there was an apparent combined sex and age effect, such that older men had the least favourable changes over time (Figure 1).

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80. No differences in results were seen.

DISCUSSION

In this analysis of a single cohort of Australian adults, weight and WC increased in the most recent period in all population sub-groups examined. Annual weight gain between 2005–2012 was less than between 1999/2000–2005, but annual WC gain was greater. Improvements over time were not seen in older men or those with greatest area-level social disadvantage.

The lack of difference in annual weight and WC change between the two periods observed for current smokers, those from a non-English speaking background and those with obesity, is likely to reflect small sample sizes in these groups. In general, adjustment for covariates had little effect on the observed associations between study period and annual weight and WC change. As time spent watching TV, exercise and energy intake might be expected to be mediating some of the observed changes, we had expected a greater impact after adjustment for these factors. The lack of impact after adjustment likely reflects that they are relatively blunt instruments to detect small changes in behaviour over time.

The general observation that annual weight gain may be lessening over time supports the cross-sectional time series observations of a plateau in the prevalence of obesity and rate of change in BMI. However, these results also suggest that the general observations do not tell the whole story, with large differences between different population subgroups, and a contrasting observation for waist circumference. The sex differences observed here are similar to the cross-sectional trends reported for American adults for whom a clear plateau in obesity prevalence has been observed for women but not men [2]. The differences we observed according to level of area-level disadvantage also reflect findings from the review of obesity trends in which the levelling off of obesity was generally more pronounced in groups with higher socio-economic position [1]. It is possible, based on current reports of levelling off of obesity prevalence in children, that different trends would be observed in Australian children, and it will be important to do a similar analysis in a longitudinal children's cohort.

The observation that rates of WC change may be continuing to increase even as rates of weight change decrease may reflect prior findings using the NHANES data that WC is increasing to a greater extent than expected from changes in weight [12] [13]. While we observed changes in weight and WC to be highly correlated these results combined suggest a preferential increase in abdominal adiposity over time, which is thought to be associated with greater risk of cardio-metabolic outcomes [14]. The potential implication that current bodyweight trends are leading a more metabolically active obesity, with increased risks for outcomes such as diabetes, hypertension and cardiovascular disease warrants further investigation.

The key strength of the current study is that for the first time it addresses this important question through an analysis of the same cohort of adults over two distinct but recent time periods. In doing this, conclusions can be drawn about the changes over time independent of unmeasurable differences in cohorts. Other strengths include the national population sampling strategy of the AusDiab cohort and the measured weight and WC at each study wave.

The potential limitation of the current study is the lack of generalisability of the included cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who attended all three waves are more select again, with higher educational attainment and a lower prevalence of chronic disease and risk factors. It is possible that a generally more healthy and health conscious population has a stronger response to population health messages, and consequently the decrease in weight gain observed here over time may be greater than would be observed for the general population. However, the current observations lend support to the concept that weight gain is decreasing over time in the population, even if the AusDiab cohort represents a particularly sensitive indicator.

The results also suggest there is no room for complacency in obesity prevention. The rates of overweight and obesity remain high, the average change in weight and WC remains an increase and there is no reduction in annual WC gain. Further, no improvements in weight or WC change were observed in older men. Finally, the observation that no improvements in rates of weight and WC change are being seen by those living in the most socially disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the social inequalities in obesity, and consequent ill health [15]. It is critical that further studies are conducted to confirm these findings and that we work to identify the causes of the observed improvements, as well as the lack of improvement in WC and specific population sub-groups.

336 In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While some obesity prevention strategies may be working, they are not affecting WC, older men or those in lower SEP groups.

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Figures

Figure 1. Difference in annual change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

406 **Tables**

407 **Table 1** Comparison of characteristics in 1999/2000 between the included and excluded
408 population

Baseline characteristics	Included	Excluded
n	3351	7896
Sex (% men)	45	45
Age (mean, y)*	49 (11)	52 (16)
Education (% post high school)*	67	56
Area-level disadvantage (% in lowest tertile)	25	36
Born in Australia or New Zealand (%)	80	74
Never smoker (%)*	63	51
Weight (mean, kg)	76 (16)	78 (17)
Waist circumference (mean, cm)	89 (13)	92 (14)
Energy intake (mean, kj/day)	8225 (3112)	8137 (3566)
TV viewing time (mean, minutes/week)	703 (512)	829 (613)
Exercise Time (mean, minutes/week)	283 (329)	269 (332)
Diabetes (%)*	4.9	10.1
Coronary heart disease (%)*	2	5
Hypertension (%)	23	29
High blood cholesterol (%)	26	25

409 Notes: data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 2 Characteristics of the cohort in 1999/2000 and 2005

Cross-sectional characteristics	2000	2005
Age (mean, y)*	49.3 (11.1)	54.3 (11.1)
Weight (mean, kg)	76.2 (15.6)	77.9 (16.3)
Waist circumference (mean, cm)	89.4 (13.4)	91.6 (13.6)
Smoking status (% never)	63	61
Diabetes (%)	4.9	6.4
Exercise time (mean, minutes/week)*	283 (330)	306 (338)
TV time (mean, minutes/week)*	703 (512)	764 (539)
Energy intake (mean, kj/day)*	8225 (3112)	7681 (2998)
Changes during follow-up	**Period 1**	**Period 2**
Weight change (mean, kg)	1.7 (5.2)	0.9 (6.1)
Waist circumference change (mean,	2.1 (6.2)	3.2 (6.9)
Follow-up (mean, y)*	5.0 (0.15)	6.9 (0.34)
Proportion gaining weight (%)*	64.5	56.8
Annual weight change (mean, kg/y)*	0.34 (1.04)	0.13 (0.89)
Annual WC change (mean, cm/y)	0.43 (1.25)	0.46 (1.00)

Notes: Data are % or mean (SD) *Indicates a significant difference (p<0.05)

Table 3 Change in Period 2 compared to Period 1 in annual weight change (kg/year) (A); and waist circumference change (cm/year) (B)

(A)

	Sample size	Annual weight change in Period 1	Change in Period 2 compared to change in Period 1		
			Model 1	**Model 2**	**Model 3**
Total Population	3351	0.34 (0.30-0.37)	-0.11 (-0.15--0.06)*	-0.10 (-0.15--0.06)*	-0.10 (-0.15--0.06)*
Men	1503	0.29 (0.24-0.34)	-0.08 (-0.14--0.01)*	-0.07 (-0.14--0.01)*	-0.08 (-0.15--0.01)*
Women	1848	0.37 (0.32-0.42)	-0.13 (-0.20--0.07)*	-0.13 (-0.19--0.06)*	-0.13 (-0.19--0.06)*
Age<55	2311	0.46 (0.41-0.50)	-0.12 (-0.19--0.06)*	-0.12 (-0.18--0.06)*	-0.13 (-0.19--0.06)*
Age>=55	1040	0.07 (0.01-0.12)	-0.08 (-0.15--0.02)*	-0.08 (-0.15--0.01)*	-0.07 (-0.14--0.01)*
Education- secondary & trade certificate	2073	0.34 (0.30-0.39)	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*
Education- diploma & degree	1278	0.32 (0.27-0.38)	-0.07 (-0.14-0.00)	-0.07 (-0.14-0.00)	-0.06 (-0.14-0.01)
Area level disadvantage- tertile of most	1096	0.31 (0.24-0.37)	-0.01 (-0.09-0.07)	-0.01 (-0.09-0.07)	-0.01 (-0.10-0.07)

disadvantage					
Area level disadvantage-middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31--0.14)*	-0.22 (-0.31--0.14)*	-0.22 (-0.31--0.14)*
Area level disadvantage-tertile of least disadvantage	1125	0.30 (0.24-0.35)	-0.08 (-0.16--0.01)*	-0.08 (-0.15--0.00)*	-0.08 (-0.15--0.00)*
Normal weight	1342	0.4 (0.36-0.44)	-0.07 (-0.13--0.01)*	-0.07 (-0.13--0.01)*	-0.08 (-0.14--0.02)*
Overweight	1375	0.31 (0.26-0.37)	-0.12 (-0.18--0.05)*	-0.11 (-0.18--0.04)*	-0.12 (-0.19--0.05)*
Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*	-0.15 (-0.29--0.01)*
English speaking country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15--0.06)*	-0.1 (-0.15--0.05)*	-0.1 (-0.15--0.05)*
Non-English speaking country of birth	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)	-0.15 (-0.33-0.03)
Never smokers	2121	0.34 (0.29-0.38)	-0.10 (-0.15--0.04)*	-0.1 (-0.15--0.04)*	-0.10 (-0.15--0.04)*
Ex smokers	894	0.27 (0.20-0.34)	-0.15 (-0.24--0.06)*	-0.15 (-0.24--0.06)*	-0.16 (-0.25--0.07)*
Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)	0.00 (-0.20-0.19)
No chronic disease#	1944	0.42 (0.37-0.47)	-0.10 (-0.16--0.04)*	-0.10 (-0.16--0.04)*	-0.09 (-0.15--0.03)*

Chronic disease#	1407	0.25 (0.20-0.30)	-0.12 (-0.19--0.05)*	-0.11 (-0.19--0.04)*	-0.10 (-0.17--0.02)*

(B)

	Sample size	Annual WC change in Period 1	Model 1	Model 2	Model 3
Total Population	3351	0.43 (0.39-0.48)	0.07 (0.02-0.12)*	0.07 (0.02-0.13)*	0.07 (0.01-0.12)*
Men	1503	0.32 (0.26-0.38)	0.13 (0.05-0.20)*	0.13 (0.06-0.21)*	0.12 (0.05-0.20)*
Women	1848	0.53 (0.47-0.59)	0.02 (-0.06-0.10)	0.03 (-0.05-0.11)	0.02 (-0.05-0.10)
Age<55	2311	0.50 (0.45-0.55)	0.05 (-0.03-0.12)	0.05 (-0.02-0.13)	0.05 (-0.03-0.12)
Age>=55	1040	0.28 (0.21-0.35)	0.10 (0.02-0.18)*	0.10 (0.02-0.19)*	0.10 (0.02-0.18)*
Education- secondary & trade certificate	2073	0.44 (0.39-0.49)	0.09 (0.02-0.15)*	0.09 (0.02-0.16)*	0.08 (0.01-0.15)*
Education- diploma & degree	1278	0.43 (0.36-0.50)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)
Area level disadvantage- tertile of most disadvantage	1096	0.41 (0.34-0.49)	0.13 (0.04-0.23)*	0.13 (0.04-0.23)*	0.14 (0.04-0.23)*
Area level disadvantage- middle tertile	1130	0.32 (0.24-0.40)	0.21 (0.11-0.31)*	0.22 (0.12-0.32)*	0.22 (0.12-0.32)*
Area level disadvantage- tertile of least disadvantage	1125	0.57 (0.50-0.64)	-0.14 (-0.23--0.05)*	-0.13 (-0.22--0.05)*	-0.15 (-0.23--0.06)*

Normal weight	1342	0.48 (0.42-0.54)	0.04 (-0.04-0.12)	0.04 (-0.04-0.12)	0.03 (-0.05-0.12)
Overweight	1375	0.43 (0.36-0.49)	0.08 (-0.01-0.16)	0.08 (-0.00-0.17)	0.07 (-0.02-0.15)
Obese	633	0.35 (0.24-0.46)	0.12 (-0.01-0.26)	0.13 (-0.00-0.27)	0.11 (-0.02-0.25)
English speaking country of birth	3129	0.44 (0.40-0.48)	0.06 (0.01-0.12)*	0.07 (0.01-0.13)*	0.06 (0.01-0.12)*
Non-English speaking country of birth	222	0.35 (0.18-0.52)	0.17 (-0.04-0.38)	0.18 (-0.02-0.39)	0.17 (-0.03-0.38)
Never smokers	2121	0.44 (0.39-0.49)	0.07 (0.00-0.14)*	0.07 (0.01-0.14)*	0.07 (0.00-0.14)*
Ex smokers	894	0.38 (0.30-0.46)	0.04 (-0.06-0.14)	0.04 (-0.06-0.14)	0.03 (-0.08-0.13)
Current smokers	336	0.56 (0.40-0.71)	0.17 (-0.05-0.39)	0.17 (-0.05-0.40)	0.18 (-0.04-0.41)
Chronic disease[1]	1944	0.47 (0.41-0.52)	0.06 (-0.01-0.13)	0.07 (-0.01-0.14)	0.07 (-0.01-0.14)
No chronic disease[1]	1407	0.44 (0.39-0.49)	0.08 (-0.00-0.17)	0.09 (0.00-0.17)*	0.1 (0.01-0.18)*

Model 1- adjusting for age and sex

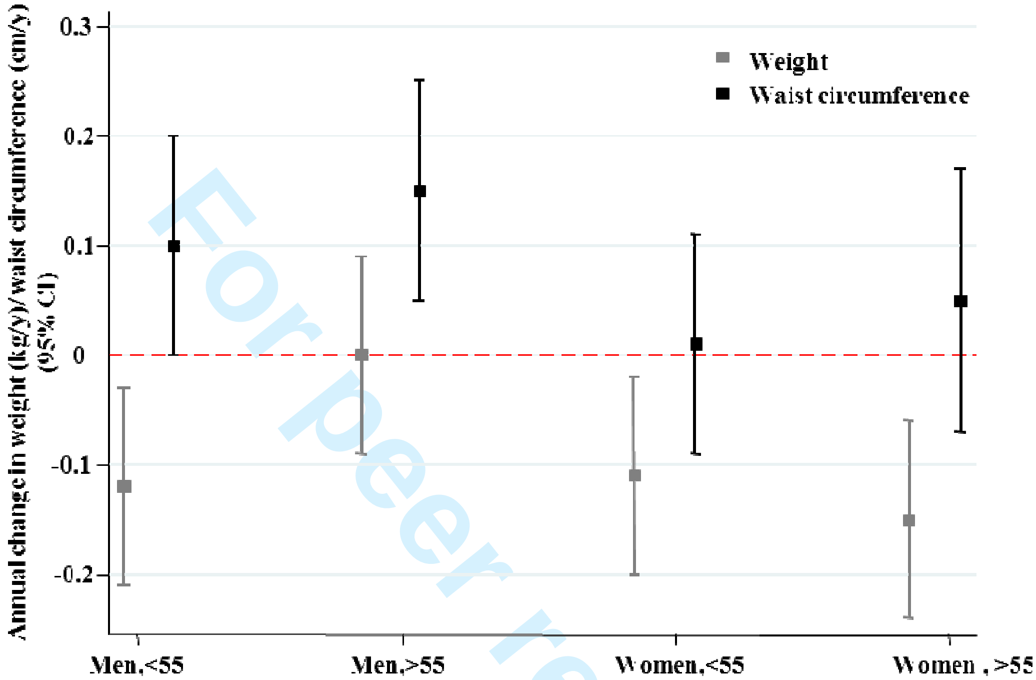
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

Model 3- additionally adjusting for baseline BMI and diabetes status

* indicates $p<0.05$

1 Chronic disease refers to any of coronary heart disease, cholesterol, hypertension, or diabetes at baseline

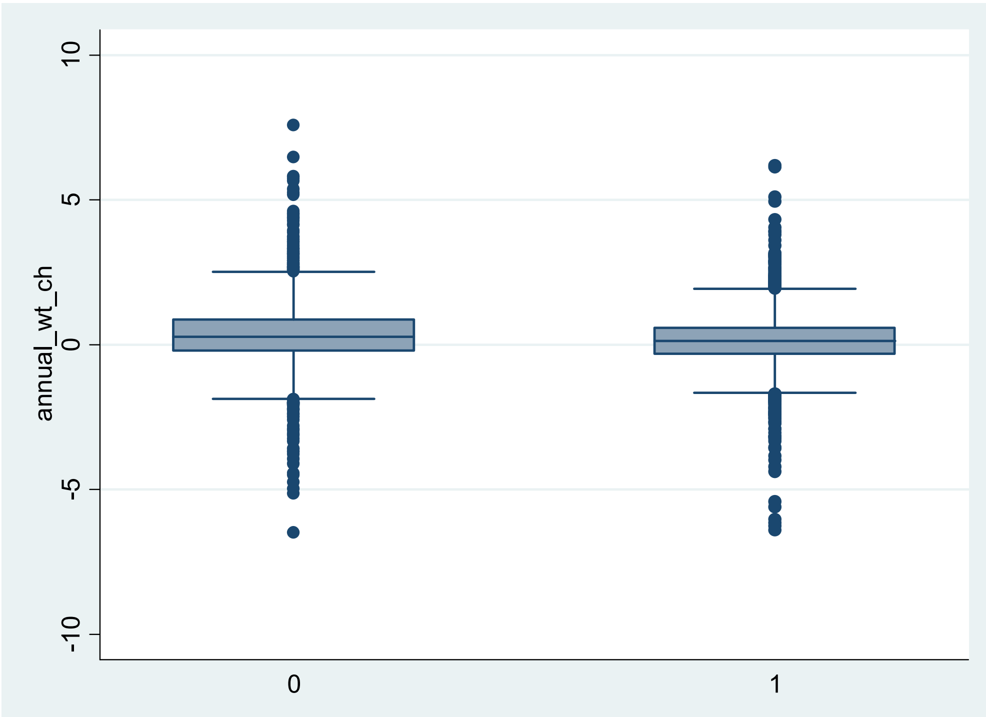
Figure 1. Difference in annual change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.



Appendix

Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



B. Annual waist circumference change

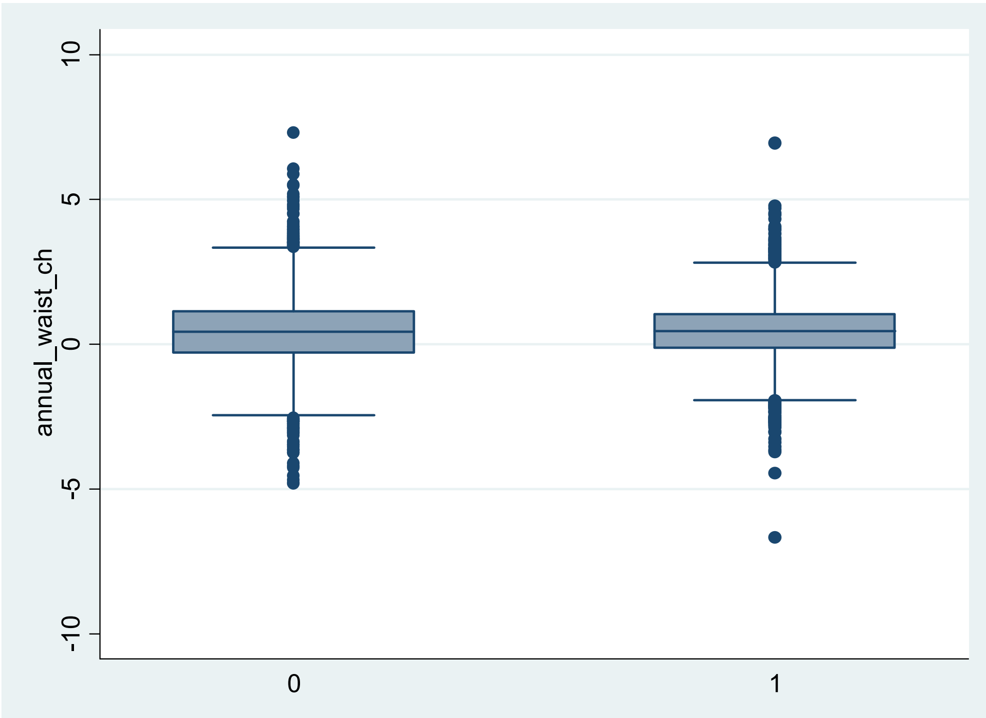


Table 1 Comparison of annual weight and waist circumference change between Period 1 and Period 2 for matching age groups.

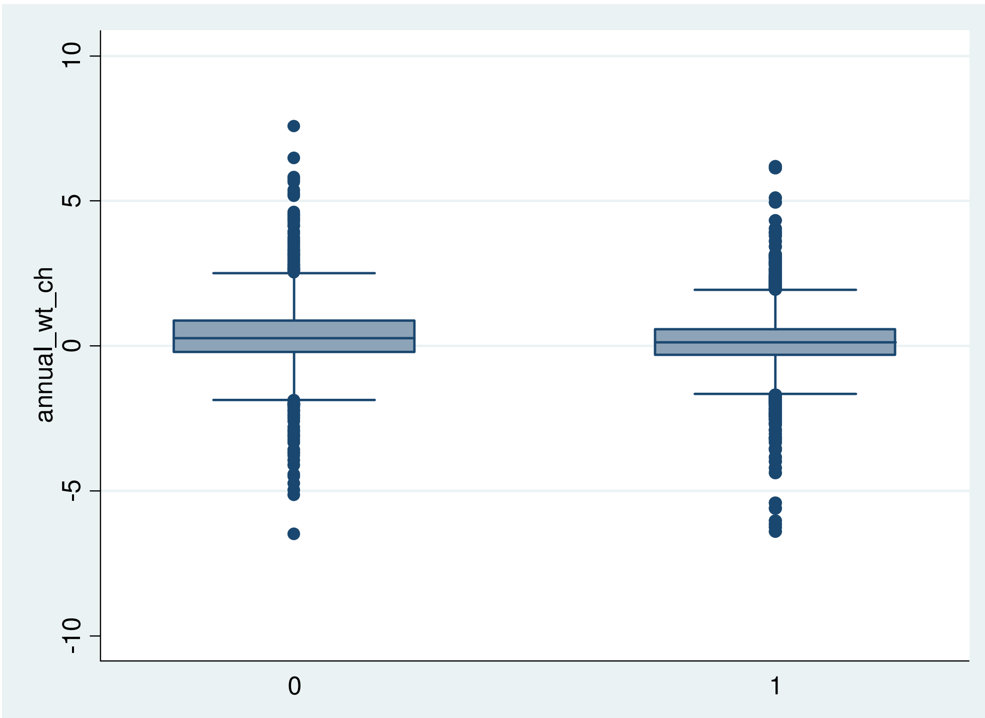
Sex	Age group	Difference in annual weight change	Difference in annual WC change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference (p<0.05)

Appendix

Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



B. Annual waist circumference change

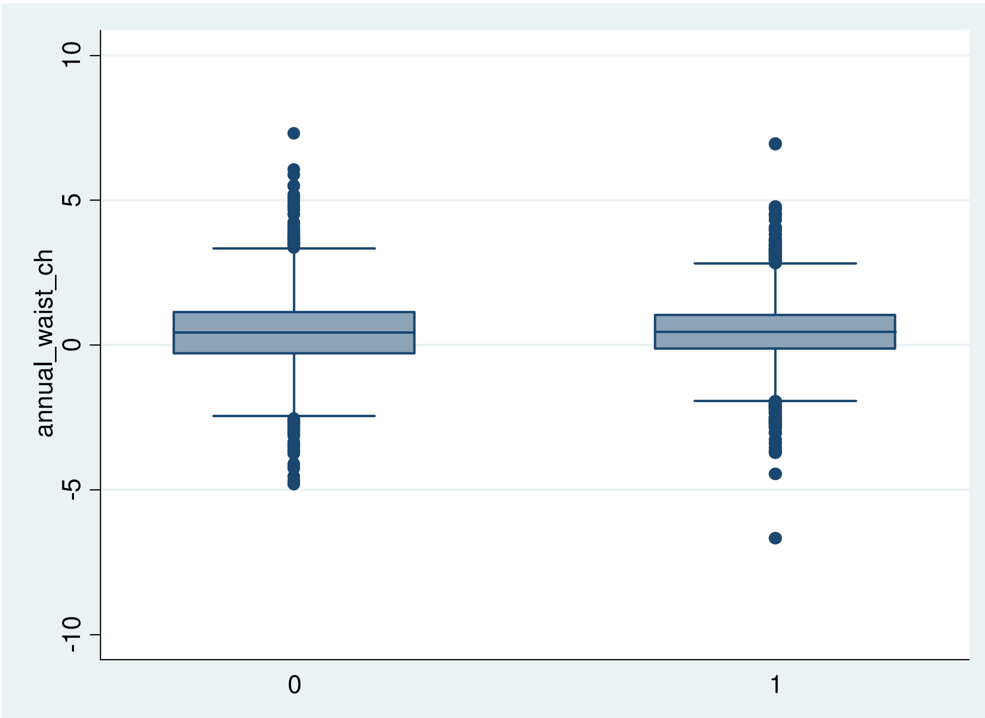


Table 1 Comparison of annual weight and waist circumference change between Period 1 and Period 2 for matching age groups.

Sex	Age group	Difference in annual weight change	Difference in annual WC change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference ($p<0.05$)

Changes in the rates of weight and waist circumference gain in Australian adults over time

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Changes in the rates of weight and waist circumference gain in Australian adults over time.

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ABSTRACT

Objective: To assess in a single cohort whether annual weight and waist circumference (WC) change has varied over time.

Design: Longitudinal cohort study with three surveys, 1 – 1999/2000; 2 – 2004/2005; 3 – 2011/2012. Generalized linear mixed models with random effects were used to compare annualised weight and WC change between surveys 1 and 2 (Period 1) with that between surveys 2 and 3 (Period 2). Models were adjusted for age to analyse changes with time rather than age. Models were additionally adjusted for sex, education status, area-level socio-economic disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

Setting: The Australian Diabetes, Obesity and Lifestyle study (AusDiab) - a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years.

Participants: 3,351 Australian adults who attended each of three surveys and had complete measures of weight, WC and covariates.

Primary outcome measures: Weight and WC were measured according to standard protocols at each survey. Change in weight and WC was annualised for comparison between the two Periods.

Results: Mean weight and WC increased in both Periods. Annualised weight gain in Period 2 was 0.11kg/year (95% CI 0.06–0.15) less than in Period 1. Lesser annual weight gain between the two periods was not seen for those with greatest area-level socio-economic disadvantage, or in men over the age of 55. In contrast, the annualised WC increase in Period 2 was greater than in Period 1 (0.07cm/year, 95% CI 0.01–0.12). The increase was greatest in males 55+ and those with greater area-level socio-economic disadvantage.

Conclusions: Between 2004/5–2011/2, Australian adults in a national study continued to gain weight, but more slowly than 1999/2000–2004/5. While weight gain may be slowing, it does not appear to be affecting older men or those in more disadvantaged groups, and the same cannot be said for WC.

Article summary

Article focus

- We aimed to assess in a single cohort whether change in weight and waist circumference has changed in recent time periods, independent of age.

Key messages

- Between 2004/5–2011/2, Australian adults in this national cohort study continued to gain weight, but more slowly than 1999/2000–2004/5.
- In contrast waist circumference gain was greater in the most recent period. Important differences were observed according to area-level socio-economic disadvantage.
- While weight gain may be slowing, this has not been observed for older men or those in more disadvantaged groups.

Strengths and limitations

- Reliably measured data in a single nationally representative cohort in recent time periods
- Analyses adjusted and matched for age for comparison between Periods to enable analysis of changes over time, rather than age
- Selection and response bias may limit the generalisability of the results to the broader Australian population

Obesity in adults has increased rapidly over the past few decades, leading to prevalence of over one quarter in many developed countries [1]. There is growing acceptance that strong preventive measures are required to stem the increasing prevalence, with a variety of approaches implemented, ranging from social marketing through whole of community interventions to regulatory strategies.

There have been some suggestions that obesity prevention interventions in children have had a positive effect, due to the observation that the prevalence of obesity is no longer increasing at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity prevalence at two time points since 1999 [4] concluded that in more developed nations a likely slowing of the rate of increase in obesity prevalence was occurring in children, with a possible turning point around 2000. However, trends in adults in this review generally appeared to be continuing to increase. Since this review, an analysis of US adults through the repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that time period in non-Hispanic white and Hispanic women, but continued increases in men and non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data suggests a continued increase in obesity prevalence in adults to 2012 [6]. However, prevalence data is driven by a range of factors, including migration, mortality and response bias. To determine whether the degree of weight gain in the population has slowed over time, a comparison of the rates of weight change is required.

We aimed to analyse whether the degree of change in weight and waist circumference (WC) over time differed in a single cohort of adults, comparing weight and WC change in the same individuals between two consecutive time periods, adjusting for age. We used the national Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared annualised change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

METHODS

Setting and Participants

The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years, recruited in 1999 -2000 (AusDiab1). Methods and response rates have been described previously[7]. Five-year follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3, respectively. For this analysis we excluded participants with missing data on weight or WC at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a final sample size of 3,351. Ethics approval was obtained from the International Diabetes Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented to participate in the study.

All study assessments followed a similar protocol [8] [7]. Data were collected by interviewer-administered questionnaires on medical history, lifestyle and health behaviour.

Outcomes

Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm. Weight was measured without shoes, excess clothing, and items in pockets by a single measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior to each set of measurements. BMI was obtained from the calculation of weight (kg) divided

by height (m^2). Annual weight change was calculated as the difference in weight between AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time between the two consecutive surveys.

Waist circumference was measured twice, halfway between the lower border of the ribs and the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the mean of the two closest measurements was calculated. Annualised WC change was calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by the follow-up time between the two consecutive surveys.

Co-factors

Data on education, country of birth, smoking and physical activity and television viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was ascertained by asking if participants had been told by a doctor or nurse that they had angina, myocardial infarction, or stroke.

Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked tobacco daily) combined [9] [7].

Education level was ascertained by asking the question "Which of these describes the highest qualification you have received?" Education was categorised as secondary only (comprising those with a secondary school qualification), diploma (comprising nursing or teaching qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor degree, post-graduate diploma or masters degree/doctorate)[10].

Area-level socio-economic disadvantage was estimated using the Index of Relative Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was

developed by the Australian Bureau of Statistics, to create a summary measure from a group of 20 variables (related to education, income, employment, family composition, housing benefits, car ownership, ethnicity, English language proficiency, residential overcrowding) displaying dimensions of social disadvantage [11]. The index is constructed so that high values reflect areas with high socio-economic status (relative advantage) and low values reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage were calculated amongst the final study sample.

Physical activity was measured via an interviewer-administered Active Australia questionnaire, which considered participation in predominantly leisure-time physical activities (including walking for transport) during the previous week [12]. Total physical activity time was calculated as the sum of the time spent walking (if continuous and for ≥10 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-intensity physical activity [13].

Self-reported television viewing time was calculated as the total time spent watching television or videos in the previous week, and is considered a reliable and valid estimate of television viewing time among adults [14].

Average daily energy intake was assessed using a self-administered food frequency questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with additional questions on food habits, portion size and consumption of alcoholic beverages. In AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential measurement error, manual blood pressure measurements were adjusted as previously described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.

Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus Optical, Tokyo, Japan) at a central laboratory [17].

Classification of diabetes status has been described elsewhere [17]. Briefly, participants were classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and were either taking hypoglycaemic medication or had fasting plasma glucose (FPG) ≥7.0mmol/L or a 2-hour plasma glucose (PG)≥ 11.1mmol/L. Participants not reporting diabetes but with FPG≥7.0mmol/L or 2-hour PG≥ 11.1mmol/L were classified as having 'newly diagnosed diabetes'.

Statistical analysis

Baseline characteristics (means and proportions at AusDiab1) were compared between AusDiab participants with and without complete measures at AusDiab 1, 2 and 3. Characteristics of the included population were also compared in 2000 and 2005, representing the two baseline surveys for the two weight change periods.

The difference in annualised weight and WC change in Period 1 (2000 to 2005), compared to Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear mixed models with random effects were used to analyse the association between study period on annual weight or WC change. This model includes random effects associated with both the cluster and the units of analysis (participants) to take the clustered structure of the data into account and to allow the residuals associated with the longitudinal measures on the same unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model 1), additionally adjusting for smoking, education, area level disadvantage and country of birth (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4). Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2 for change in Period 2. Adjustment for age enables the differences in weight and WC change

observed between the two Periods to be attributed to time rather than age. The association between study period and annualised weight and WC change was also analysed across sub-groups and interaction terms between study period with age or sex were analysed.

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80.

All analyses were performed in STATA (version 11.0), with statistical significance set at the 5% level.

RESULTS

The population with complete measures was similar to the total AusDiab cohort with respect to sex and weight, but was younger, with higher educational attainment, and a higher prevalence of never smoking (Table 1). The population with complete measures also had a lower prevalence of chronic disease. There was no appreciable difference between the two groups for weight change in Period 1 after adjustment for differences in age and sex.

(Table 1 here)

Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to being five years older, the population had a higher prevalence of diabetes (predominantly type 2). In both periods the average change in weight and WC was a gain. In Period 2, a smaller proportion of the population gained weight and annualised weight gain was less, at 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser weight change across the entire distribution of weight change in Period 2, with minimal difference at the 5^{th} percentile, increasing to a difference of 0.50kg/year at the 95^{th} percentile of weight change (Appendix Figure 1A). For WC, there was no difference in the crude annualised change between the two periods (Table 2). In contrast to weight change, this resulted from both a smaller gain in those whose WC increased and a smaller loss in those whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

(Table 2 here)

Comparison of the crude annualised weight change for matching 10-year age-groups in Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups, although these differences were only significant for men aged 35–44, and women 45–54 and

65–74 (Appendix Table 1). Comparison of the crude annualised WC change for matching age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64; Appendix Table 1).

The difference in annualised weight and WC change in Period 2, compared to Period 1, was assessed using linear regression analysis (Table 3A). In Period 2, annualised weight gain was 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after further adjustment for smoking status, education status, ethnicity, area-level socio-economic disadvantage, baseline BMI and diabetes status (Table 3A), nor after adjustment for TV time, exercise time and energy intake (results not shown).

Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 3A), with suggestions of a greater difference over time in women, and those aged under 55 years (although no interaction tests on these factors were significant). Annualised weight gain in Period 2 was non-significantly less than in Period 1 for those with high educational attainment (borderline significant), obesity, and those from a non-English speaking background. No difference in annualised weight gain between the two periods was observed for those in the tertile of greatest area-level socio-economic disadvantage, nor for current smokers.

In Period 2, annualised WC gain was 0.07 cm/year more than in Period 1 (Table 3B). This did not alter substantially after further adjustment for smoking status, education status, area-level socio-economic disadvantage, ethnicity, baseline BMI and diabetes status (Table 3B), nor after adjustment for TV time, exercise time and energy intake (results not shown).

In stratified analyses no difference in annualised WC gain between the two periods was observed for women, those aged<55 years, those in the highest education group, those with normal weight nor ex-smokers. Annualised WC gain was less in Period 2 than Period 1 for those in the tertile of least area-level socio-economic disadvantage (-0.14cm/year 95%CI -.05, -0.23).

(Table 3 here)

For both weight and WC, there was an apparent combined sex and age effect, such that older men had the least favourable changes over time (Figure 1).

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80. No differences in results were seen.

DISCUSSION

In this analysis of a single cohort of Australian adults, weight and WC increased in the most recent period in all population sub-groups examined. Age-adjusted annualised weight gain between 2005–2012 was less than between 1999/2000–2005, but annualised WC gain was greater. Lesser weight gain over time was not seen in older men or those with greatest area-level socio-economic disadvantage.

The lack of difference in weight and WC change between the two periods observed for current smokers, those from a non-English speaking background and those with obesity, is likely to reflect small sample sizes in these groups. In general, adjustment for covariates had little effect on the observed associations between study period and weight and WC change. As time spent watching TV, exercise and energy intake might be expected to be mediating much of the observed changes, we had expected an observable reduction in the difference between study periods after adjustment for these factors. The lack of impact after adjustment likely reflects that they are relatively blunt instruments to detect small changes in behaviour over time. The self-reported nature of these behavioural questionnaires is associated with both differential and non-differential error [18] [19]. While validated, the FFQ is has a limited list of foods and is affected by the inability of individuals to accurately report their food intake retrospectively over a long period of time [20]. Further the Active Australia questionnaire only refers to leisure time activity and TV watching is only one component of sitting time.

The general observation that weight gain may be lessening over time supports the cross-sectional time series observations of a plateau in the prevalence of obesity and rate of change in BMI [4]. However, these results also suggest that the general observations do not tell the whole story, with large differences between different population subgroups, and a contrasting observation for waist circumference. The sex differences observed here are similar to the cross-sectional trends reported for American adults for whom a clear plateau in obesity prevalence has been observed for women but not men [5]. The differences we observed according to level of area-level socio-economic disadvantage also reflect findings from the review of obesity trends in which the levelling off of obesity was generally more pronounced in groups with higher socio-economic position [4]. It will be important to do a similar analysis in a longitudinal children's cohort, as their experience is likely to differ from that of adults. Children have been exposed to a wide range of obesity prevention interventions, particularly in schools, in countries such as Australia and cross-sectional trends clearly suggest a plateauing in the prevalence of obesity in children [4].

The observation that rates of WC change may be continuing to increase even as rates of weight change decrease may reflect prior findings using the NHANES data that WC is increasing to a greater extent than expected from changes in weight [21] [22]. While we observed changes in weight and WC to be highly correlated these results combined suggest a preferential increase in abdominal adiposity over time, which is thought to be associated with greater risk of cardio-metabolic outcomes [23]. The potential implication that current bodyweight trends are leading a more metabolically active obesity, with increased risks for outcomes such as diabetes, hypertension and cardiovascular disease warrants further investigation.

The key strength of the current study is that for the first time it addresses this important question through an analysis of the same cohort of adults over two distinct but recent time periods, independent of the effects of ageing. In doing this, conclusions can be drawn about the changes over time independent of unmeasurable differences in cohorts. Other strengths include the national population sampling strategy of the AusDiab cohort and the measured weight and WC at each study wave.

The potential limitation of the current study is the lack of generalisability of the included cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who attended all three waves are more select again, with higher educational attainment and a lower prevalence of chronic disease and risk factors. It is possible that a generally more healthy and health conscious population has a stronger response to population health messages, and consequently the lesser weight gain observed here in consecutive age cohorts over time may be greater than would be observed for the general population. However, the current observations lend support to the concept that weight gain is decreasing over time in the population, even if the AusDiab cohort represents a particularly sensitive indicator. One further potential limitation is the use of different weighing scales at AusDiab 2 and 3 compared to AusDiab1. Although all scales were calibrated in the same way at each survey wave, differences in variability between the scales may have led to more variability in the change in weight in Period 1 than Period 2.

The results also suggest there is no room for complacency in obesity prevention. The rates of overweight and obesity remain high, the average change in weight and WC remains an increase and there is no reduction in the rate of WC gain. Further, no decrease in the rate of weight or WC change were observed in older men. Finally, the observation that no decrease in rates of weight and WC change is being seen by those living in the most socially disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the social inequalities in obesity, and consequent ill health [24]. It is critical that further studies are conducted to confirm these findings and that we work to identify the causes of the observed changes, including the differences observed in specific population sub-groups.

In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While weight gain may be slowing, it does not appear to be affecting older men or those in more disadvantaged groups, and the same cannot be said for WC.

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Data sharing

Extra data is available by emailing A Peeters at anna.peeters@bakeridi.edu.au

Authorship statement

AP conceived of the article, executed the analysis and writing of the article and is guarantor for the article. JS, DM and KB contributed to the ideas included within and writing of the article, and provision of data. PZ contributed to the writing of the article and provision of data.

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Figures

Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

457 Tables

458 Table 1 Comparison of characteristics in 1999/2000 between the included and excluded
459 population

Baseline characteristics	Included	Excluded
n	3351	7896
Sex (% men)	45	45
Age (mean, y)*	49 (11)	52 (16)
Education (% post high school)*	67	56
Area-level disadvantage (% in lowest tertile)	25	36
Born in Australia or New Zealand (%)	80	74
Never smoker (%)*	63	51
Weight (mean, kg)	76 (16)	78 (17)
Waist circumference (mean, cm)	89 (13)	92 (14)
Energy intake (mean, kj/day)	8225 (3112)	8137 (3566)
TV viewing time (mean, minutes/week)	703 (512)	829 (613)
Exercise Time (mean, minutes/week)	283 (329)	269 (332)
Diabetes (%)*	4.9	10.1
Coronary heart disease (%)*	2	5
Hypertension (%)	23	29
High blood cholesterol (%)	26	25

460 Notes: data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 2 Characteristics of the cohort in 1999/2000 and 2005

Cross-sectional characteristics	2000	2005
Age (mean, y)*	49.3 (11.1)	54.3 (11.1)
Weight (mean, kg)	76.2 (15.6)	77.9 (16.3)
Waist circumference (mean, cm)	89.4 (13.4)	91.6 (13.6)
Smoking status (% never)	63	61
Diabetes (%)	4.9	6.4
Exercise time (mean, minutes/week)*	283 (330)	306 (338)
TV time (mean, minutes/week)*	703 (512)	764 (539)
Energy intake (mean, kj/day)*	8225 (3112)	7681 (2998)
Changes during follow-up	Period 1	Period 2
Weight change (mean, kg)	1.7 (5.2)	0.9 (6.1)
Waist circumference change (mean, cm)	2.1 (6.2)	3.2 (6.9)
Follow-up (mean, y)*	5.0 (0.15)	6.9 (0.34)
Proportion gaining weight (%)*	64.5	56.8
Annualised weight change (mean, kg/y)*	0.34 (1.04)	0.13 (0.89)
Annualised WC change (mean, cm/y)	0.43 (1.25)	0.46 (1.00)

Notes: Data are % or mean (SD) *Indicates a significant difference (p<0.05)

Table 3 Change in Period 2 compared to Period 1 in annualised weight change (kg/year) (A); and waist circumference change (cm/year) (B)

(A)

	Sample size	Annualised weight change in Period 1	Change in Period 2 compared to change in Period 1		
			Model 1	Model 2	Model 3
Total Population	3351	0.34 (0.30-0.37)	-0.11 (-0.15--0.06)*	-0.10 (-0.15--0.06)*	-0.10 (-0.15--0.06)*
Men	1503	0.29 (0.24-0.34)	-0.08 (-0.14--0.01)*	-0.07 (-0.14--0.01)*	-0.08 (-0.15--0.01)*
Women	1848	0.37 (0.32-0.42)	-0.13 (-0.20--0.07)*	-0.13 (-0.19--0.06)*	-0.13 (-0.19--0.06)*
Age<55	2311	0.46 (0.41-0.50)	-0.12 (-0.19--0.06)*	-0.12 (-0.18--0.06)*	-0.13 (-0.19--0.06)*
Age>=55	1040	0.07 (0.01-0.12)	-0.08 (-0.15--0.02)*	-0.08 (-0.15--0.01)*	-0.07 (-0.14--0.01)*
Education- secondary & trade certificate	2073	0.34 (0.30-0.39)	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*
Education- diploma & degree	1278	0.32 (0.27-0.38)	-0.07 (-0.14-0.00)	-0.07 (-0.14-0.00)	-0.06 (-0.14-0.01)
Area level disadvantage- tertile of most	1096	0.31 (0.24-0.37)	-0.01 (-0.09-0.07)	-0.01 (-0.09-0.07)	-0.01 (-0.10-0.07)

disadvantage					
Area level disadvantage-middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31--0.14)*	-0.22 (-0.31--0.14)*	-0.22 (-0.31--0.14)*
Area level disadvantage-tertile of least disadvantage	1125	0.30 (0.24-0.35)	-0.08 (-0.16--0.01)*	-0.08 (-0.15--0.00)*	-0.08 (-0.15--0.00)*
Normal weight	1342	0.4 (0.36-0.44)	-0.07 (-0.13--0.01)*	-0.07 (-0.13--0.01)*	-0.08 (-0.14--0.02)*
Overweight	1375	0.31 (0.26-0.37)	-0.12 (-0.18--0.05)*	-0.11 (-0.18--0.04)*	-0.12 (-0.19--0.05)*
Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*	-0.15 (-0.29--0.01)*
English speaking country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15--0.06)*	-0.1 (-0.15--0.05)*	-0.1 (-0.15--0.05)*
Non-English speaking country of birth	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)	-0.15 (-0.33-0.03)
Never smokers	2121	0.34 (0.29-0.38)	-0.10 (-0.15--0.04)*	-0.1 (-0.15--0.04)*	-0.10 (-0.15--0.04)*
Ex smokers	894	0.27 (0.20-0.34)	-0.15 (-0.24--0.06)*	-0.15 (-0.24--0.06)*	-0.16 (-0.25--0.07)*
Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)	0.00 (-0.20-0.19)
No chronic disease#	1944	0.42 (0.37-0.47)	-0.10 (-0.16--0.04)*	-0.10 (-0.16--0.04)*	-0.09 (-0.15--0.03)*

Chronic disease#	1407	0.25 (0.20-0.30)	-0.12 (-0.19--0.05)*	-0.11 (-0.19--0.04)*	-0.10 (-0.17--0.02)*

(B)

	Sample size	Annualised WC change in Period 1	Model 1	Model 2	Model 3
Total Population	3351	0.43 (0.39-0.48)	0.07 (0.02-0.12)*	0.07 (0.02-0.13)*	0.07 (0.01-0.12)*
Men	1503	0.32 (0.26-0.38)	0.13 (0.05-0.20)*	0.13 (0.06-0.21)*	0.12 (0.05-0.20)*
Women	1848	0.53 (0.47-0.59)	0.02 (-0.06-0.10)	0.03 (-0.05-0.11)	0.02 (-0.05-0.10)
Age<55	2311	0.50 (0.45-0.55)	0.05 (-0.03-0.12)	0.05 (-0.02-0.13)	0.05 (-0.03-0.12)
Age>=55	1040	0.28 (0.21-0.35)	0.10 (0.02-0.18)*	0.10 (0.02-0.19)*	0.10 (0.02-0.18)*
Education- secondary & trade certificate	2073	0.44 (0.39-0.49)	0.09 (0.02-0.15)*	0.09 (0.02-0.16)*	0.08 (0.01-0.15)*
Education- diploma & degree	1278	0.43 (0.36-0.50)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)
Area level disadvantage- tertile of most disadvantage	1096	0.41 (0.34-0.49)	0.13 (0.04-0.23)*	0.13 (0.04-0.23)*	0.14 (0.04-0.23)*
Area level disadvantage- middle tertile	1130	0.32 (0.24-0.40)	0.21 (0.11-0.31)*	0.22 (0.12-0.32)*	0.22 (0.12-0.32)*
Area level disadvantage- tertile of least disadvantage	1125	0.57 (0.50-0.64)	-0.14 (-0.23--0.05)*	-0.13 (-0.22--0.05)*	-0.15 (-0.23--0.06)*

Normal weight	1342	0.48 (0.42-0.54)	0.04 (-0.04-0.12)	0.04 (-0.04-0.12)	0.03 (-0.05-0.12)
Overweight	1375	0.43 (0.36-0.49)	0.08 (-0.01-0.16)	0.08 (-0.00-0.17)	0.07 (-0.02-0.15)
Obese	633	0.35 (0.24-0.46)	0.12 (-0.01-0.26)	0.13 (-0.00-0.27)	0.11 (-0.02-0.25)
English speaking country of birth	3129	0.44 (0.40-0.48)	0.06 (0.01-0.12)*	0.07 (0.01-0.13)*	0.06 (0.01-0.12)*
Non-English speaking country of birth	222	0.35 (0.18-0.52)	0.17 (-0.04-0.38)	0.18 (-0.02-0.39)	0.17 (-0.03-0.38)
Never smokers	2121	0.44 (0.39-0.49)	0.07 (0.00-0.14)*	0.07 (0.01-0.14)*	0.07 (0.00-0.14)*
Ex smokers	894	0.38 (0.30-0.46)	0.04 (-0.06-0.14)	0.04 (-0.06-0.14)	0.03 (-0.08-0.13)
Current smokers	336	0.56 (0.40-0.71)	0.17 (-0.05-0.39)	0.17 (-0.05-0.40)	0.18 (-0.04-0.41)
Chronic disease[1]	1944	0.47 (0.41-0.52)	0.06 (-0.01-0.13)	0.07 (-0.01-0.14)	0.07 (-0.01-0.14)
No chronic disease[1]	1407	0.44 (0.39-0.49)	0.08 (-0.00-0.17)	0.09 (0.00-0.17)*	0.1 (0.01-0.18)*

Model 1- adjusting for age and sex

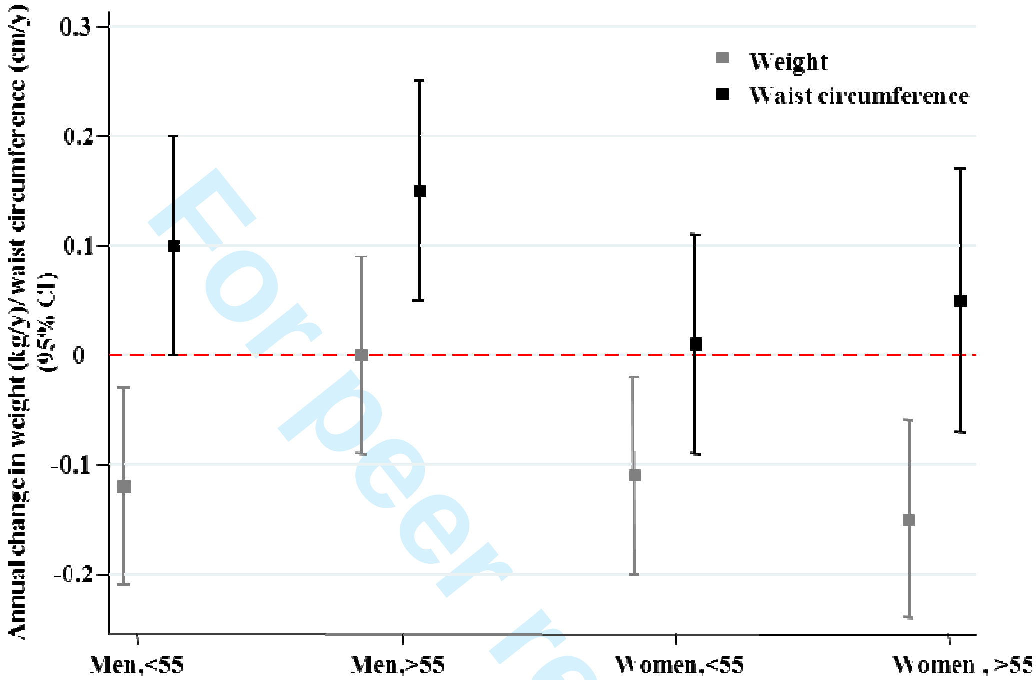
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

Model 3- additionally adjusting for baseline BMI and diabetes status

* indicates $p<0.05$

1 Chronic disease refers to any of coronary heart disease, cholesterol, hypertension, or diabetes at baseline

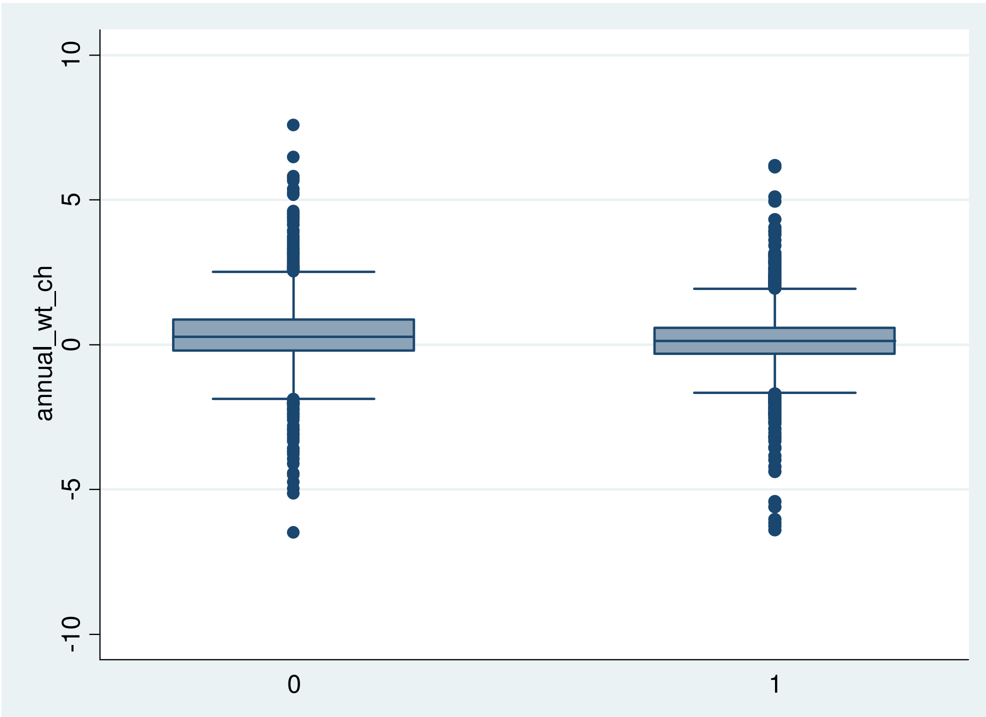
Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.



Appendix

Figure 1 Annualised weight and waist circumference change in Period 1 and Period 2

A. Annualised weight change



B. Annualised waist circumference change

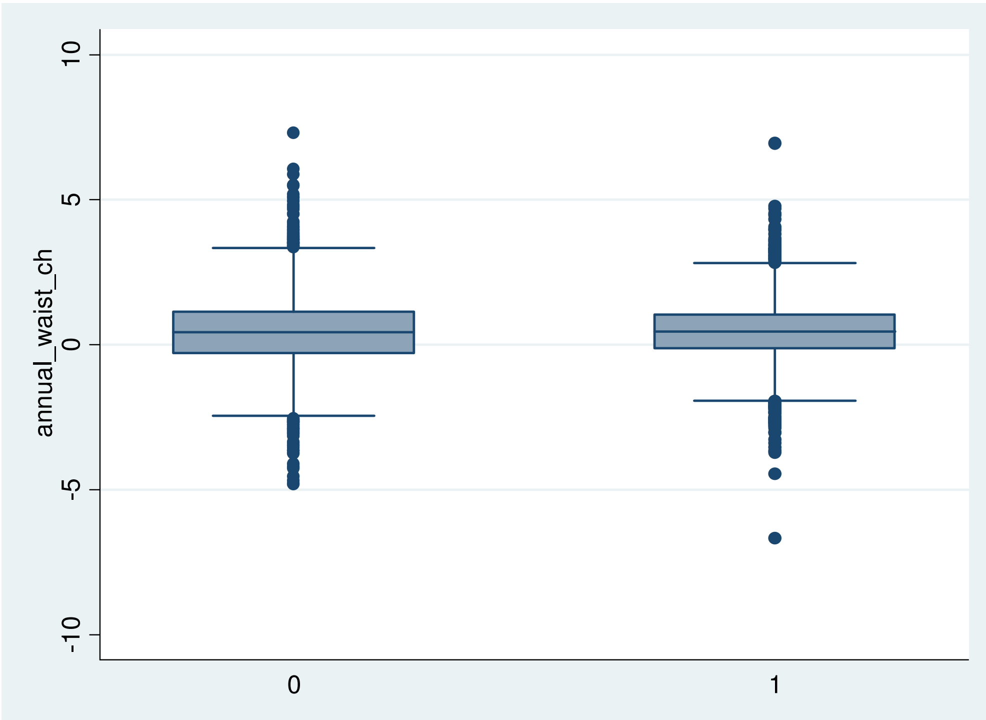


Table 1 Comparison of annualised weight and waist circumference change between Period 1 and Period 2 for matching age groups.

Sex	Age group	Difference in annualised weight change	Difference in annualised WC change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference (p<0.05)

Changes in the rates of weight and waist circumference gain in Australian adults over time.

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AP conceived of the article, executed the analysis and writing of the article and is guarantor for the article. JS, DM and KB contributed to the ideas included within and writing of the article, and provision of data. PZ contributed to the writing of the article and provision of data.

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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.

Article summary

Article focus

- We aimed to assess in a single cohort whether change in weight and waist circumference has changed in recent time periods, **independent of age**.

Key messages

- Between 2004/5–2011/2, Australian adults in this national cohort study continued to gain weight, but more slowly than 1999/2000–2004/5.
- In contrast waist circumference gain was greater in the most recent period. Important differences were observed according to area-level **socio-economic** disadvantage.
- **While weight gain may be slowing, this has not been observed for older men or those in more disadvantaged groups**.

Strengths and limitations

- Reliably measured data in a single nationally representative cohort in recent time periods
- **Analyses adjusted and matched for age for comparison between Periods to enable analysis of changes over time, rather than age**
- Selection and response bias may limit the generalisability of the results to the broader Australian population

ABSTRACT

Objective: To assess in a single cohort whether annual weight and waist circumference (WC) change has varied over time.

Design: Longitudinal cohort study with three surveys, 1 – 1999/2000; 2 – 2004/2005; 3 – 2011/2012. Generalized linear mixed models with random effects were used to compare **annualised** weight and WC change between surveys 1 and 2 (Period 1) with that between surveys 2 and 3 (Period 2). **Models were adjusted for age to analyse changes with time rather than age.** Models were additionally adjusted for sex, education status, area-level **socio-economic** disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

Setting: The Australian Diabetes, Obesity and Lifestyle study (AusDiab) - a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years.

Participants: 3,351 Australian adults who attended each of three surveys and had complete measures of weight, WC and covariates.

Primary outcome measures: Weight and WC were measured according to standard protocols at each survey. **Change in weight and WC was annualised for comparison between the two Periods.**

Results: Mean weight and WC increased in both Periods. **Annualised** weight gain in Period 2 was 0.11kg/year (95% CI 0.06–0.15) less than in Period 1. **Lesser** annual weight gain between the two periods was not seen for those with greatest area-level **socio-economic** disadvantage, or in men over the age of 55. In contrast, the **annualised** WC increase in Period 2 was greater than in Period 1 (0.07cm/year, 95% CI 0.01–0.12). **The increase was greatest in males 55+ and those with greater area-level socio-economic disadvantage**.

Conclusions: Between 2004/5–2011/2, Australian adults in a national study continued to gain weight, but more slowly than 1999/2000–2004/5. **While weight gain may be slowing, it does not appear to be affecting older men or those in more disadvantaged groups, and the same cannot be said for WC.**

Obesity in adults has increased rapidly over the past few decades, leading to prevalence of over one quarter in many developed countries [1]. There is growing acceptance that strong preventive measures are required to stem the increasing prevalence, with a variety of approaches implemented, ranging from social marketing through whole of community interventions to regulatory strategies.

There have been some suggestions that obesity prevention interventions in children have had a positive effect, due to the observation that the prevalence of obesity is no longer increasing at the same rate **[2] [3]**. A recent review of 52 studies, from 25 countries, comparing obesity prevalence at two time points since 1999 [4] concluded that in more developed nations a likely slowing of the rate of increase in obesity prevalence was occurring in children, with a possible turning point around 2000. However, trends in adults in this review generally appeared to be continuing to increase. Since this review, an analysis of US adults through the repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that time period in non-Hispanic white and Hispanic women, but continued increases in men and non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data suggests a continued increase in obesity prevalence in adults to 2012 [6]. However, prevalence data is driven by a range of factors, including migration, mortality and response bias. To determine whether the degree of weight gain in the population has slowed over time, a comparison of the rates of weight change is required.

We aimed to analyse whether the degree of change in weight and waist circumference (WC) over time differed in a single cohort of adults, comparing weight and WC change in the same individuals between two consecutive time periods, **adjusting for age**. We used the national Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared **annualised** change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

METHODS

Setting and Participants

The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years, recruited in 1999 -2000 (AusDiab1). Methods and response rates have been described previously[7]. Five-year follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3, respectively. For this analysis we excluded participants with missing data on weight or WC at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a final sample size of 3,351. Ethics approval was obtained from the International Diabetes Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented to participate in the study.

All study assessments followed a similar protocol [8] [7]. Data were collected by interviewer-administered questionnaires on medical history, lifestyle and health behaviour.

Outcomes

Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm. Weight was measured without shoes, excess clothing, and items in pockets by a single measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior to each set of measurements. BMI was obtained from the calculation of weight (kg) divided

by height (m^2). Annual weight change was calculated as the difference in weight between AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time between the two consecutive surveys.

Waist circumference was measured twice, halfway between the lower border of the ribs and the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the mean of the two closest measurements was calculated. **Annualised** WC change was calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by the follow-up time between the two consecutive surveys.

Co-factors

Data on education, country of birth, smoking and physical activity and television viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was ascertained by asking if participants had been told by a doctor or nurse that they had angina, myocardial infarction, or stroke.

Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked tobacco daily) combined [9] [7].

Education level was ascertained by asking the question "Which of these describes the highest qualification you have received?" Education was categorised as secondary only (comprising those with a secondary school qualification), diploma (comprising nursing or teaching qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor degree, post-graduate diploma or masters degree/doctorate)[10].

Area-level **socio-economic** disadvantage was estimated using the Index of Relative Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was

developed by the Australian Bureau of Statistics, to create a summary measure from a group of 20 variables (related to education, income, employment, family composition, housing benefits, car ownership, ethnicity, English language proficiency, residential overcrowding) displaying dimensions of social disadvantage [11]. The index is constructed so that high values reflect areas with high socio-economic status (relative advantage) and low values reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage were calculated amongst the final study sample.

Physical activity was measured via an interviewer-administered Active Australia questionnaire, which considered participation in predominantly leisure-time physical activities (including walking for transport) during the previous week [12]. Total physical activity time was calculated as the sum of the time spent walking (if continuous and for ≥10 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-intensity physical activity [13].

Self-reported television viewing time was calculated as the total time spent watching television or videos in the previous week, and is considered a reliable and valid estimate of television viewing time among adults [14].

Average daily energy intake was assessed using a self-administered food frequency questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with additional questions on food habits, portion size and consumption of alcoholic beverages. In AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential measurement error, manual blood pressure measurements were adjusted as previously described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.

Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus Optical, Tokyo, Japan) at a central laboratory [17].

Classification of diabetes status has been described elsewhere [17]. Briefly, participants were classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and were either taking hypoglycaemic medication or had fasting plasma glucose (FPG) ≥7.0mmol/L or a 2-hour plasma glucose (PG)≥ 11.1mmol/L. Participants not reporting diabetes but with FPG≥7.0mmol/L or 2-hour PG≥ 11.1mmol/L were classified as having 'newly diagnosed diabetes'.

Statistical analysis

Baseline characteristics (means and proportions at AusDiab1) were compared between AusDiab participants with and without complete measures at AusDiab 1, 2 and 3. Characteristics of the included population were also compared in 2000 and 2005, representing the two baseline surveys for the two weight change periods.

The difference in **annualised** weight and WC change in Period 1 (2000 to 2005), compared to Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear mixed models with random effects were used to analyse the association between study period on annual weight or WC change. This model includes random effects associated with both the cluster and the units of analysis (participants) to take the clustered structure of the data into account and to allow the residuals associated with the longitudinal measures on the same unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model 1), additionally adjusting for smoking, education, area level disadvantage and country of birth (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4). Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2 for change in Period 2. **Adjustment for age enables the differences in weight and WC**

change observed between the two Periods to be attributed to time rather than age. The association between study period and **annualised** weight and WC change was also analysed across sub-groups and interaction terms between study period with age or sex were analysed. The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80.

All analyses were performed in STATA (version 11.0), with statistical significance set at the 5% level.

RESULTS

The population with complete measures was similar to the total AusDiab cohort with respect to sex and weight, but was younger, with higher educational attainment, and a higher prevalence of never smoking (Table 1). The population with complete measures also had a lower prevalence of chronic disease. There was no appreciable difference between the two groups for weight change in Period 1 after adjustment for differences in age and sex.

(Table 1 here)

Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to being five years older, the population had a higher prevalence of diabetes (predominantly type 2). In both periods the average change in weight and WC was a gain. In Period 2, a smaller proportion of the population gained weight and **annualised** weight gain was less, at 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser weight change across the entire distribution of weight change in Period 2, with minimal difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile of weight change (Appendix Figure 1A). For WC, there was no difference in the crude **annualised** change between the two periods (Table 2). In contrast to weight change, this resulted from both a smaller gain in those whose WC increased and a smaller loss in those whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

(Table 2 here)

Comparison of the crude **annualised** weight change for matching 10-year age-groups in Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups, although these differences were only significant for men aged 35–44, and women 45–54 and

65–74 (Appendix Table 1). Comparison of the crude **annualised** WC change for matching age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64; Appendix Table 1).

The difference in **annualised** weight and WC change in Period 2, compared to Period 1, was assessed using linear regression analysis (Table 3A). In Period 2, **annualised** weight gain was 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after further adjustment for smoking status, education status, ethnicity, area-level **socio-economic** disadvantage, baseline BMI and diabetes status (Table 3A), nor after adjustment for TV time, exercise time and energy intake (results not shown).

Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 3A), with suggestions of a greater difference over time in women, and those aged under 55 years (although no interaction tests on these factors were significant). Annualised weight gain in Period 2 was non-significantly less than in Period 1 for those with high educational attainment (borderline significant), obesity, and those from a non-English speaking background. No difference in **annualised** weight gain between the two periods was observed for those in the tertile of greatest area-level **socio-economic** disadvantage, nor for current smokers.

In Period 2, **annualised** WC gain was 0.07 cm/year more than in Period 1 (Table 3B). This did not alter substantially after further adjustment for smoking status, education status, area-level **socio-economic** disadvantage, ethnicity, baseline BMI and diabetes status (Table 3B), nor after adjustment for TV time, exercise time and energy intake (results not shown).

In stratified analyses no difference in **annualised** WC gain between the two periods was observed for women, those aged<55 years, those in the highest education group, those with normal weight nor ex-smokers. **Annualised** WC gain was less in Period 2 than Period 1 for those in the tertile of least area-level **socio-economic** disadvantage (-0.14cm/year 95%CI -.05, -0.23).

(Table 3 here)

For both weight and WC, there was an apparent combined sex and age effect, such that older men had the least favourable changes over time (Figure 1).

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80. No differences in results were seen.

DISCUSSION

In this analysis of a single cohort of Australian adults, weight and WC increased in the most recent period in all population sub-groups examined. **Age-adjusted annualised** weight gain between 2005–2012 was less than between 1999/2000–2005, but **annualised** WC gain was greater. **Lesser weight gain** over time was not seen in older men or those with greatest area-level **socio-economic** disadvantage.

The lack of difference in weight and WC change between the two periods observed for current smokers, those from a non-English speaking background and those with obesity, is likely to reflect small sample sizes in these groups. In general, adjustment for covariates had little effect on the observed associations between study period and weight and WC change.

As time spent watching TV, exercise and energy intake might be expected to be mediating much of the observed changes, we had expected **an observable reduction in the difference between study periods** after adjustment for these factors. The lack of impact after adjustment likely reflects that they are relatively blunt instruments to detect small changes in behaviour over time. **The self-reported nature of these behavioural questionnaires is associated with both differential and non-differential error [18] [19]. While validated, the FFQ is has a limited list of foods and is affected by the inability of individuals to accurately report their food intake retrospectively over a long period of time [20]. Further the Active Australia questionnaire only refers to leisure time activity and TV watching is only one component of sitting time.**

The general observation that weight gain may be lessening over time supports the cross-sectional time series observations of a plateau in the prevalence of obesity and rate of change in BMI [4]. However, these results also suggest that the general observations do not tell the whole story, with large differences between different population subgroups, and a contrasting observation for waist circumference. The sex differences observed here are similar to the cross-sectional trends reported for American adults for whom a clear plateau in obesity prevalence has been observed for women but not men [5]. The differences we observed according to level of area-level **socio-economic** disadvantage also reflect findings from the review of obesity trends in which the levelling off of obesity was generally more pronounced in groups with higher socio-economic position [4]. **It will be important to do a similar analysis in a longitudinal children's cohort, as their experience is likely to differ from that of adults. Children have been exposed to a wide range of obesity prevention interventions, particularly in schools, in countries such as Australia and cross-sectional trends clearly suggest a plateauing in the prevalence of obesity in children [4].**

The observation that rates of WC change may be continuing to increase even as rates of weight change decrease may reflect prior findings using the NHANES data that WC is increasing to a greater extent than expected from changes in weight [21] [22]. While we observed changes in weight and WC to be highly correlated these results combined suggest a preferential increase in abdominal adiposity over time, which is thought to be associated with greater risk of cardio-metabolic outcomes [23]. The potential implication that current bodyweight trends are leading a more metabolically active obesity, with increased risks for outcomes such as diabetes, hypertension and cardiovascular disease warrants further investigation.

The key strength of the current study is that for the first time it addresses this important question through an analysis of the same cohort of adults over two distinct but recent time periods, **independent of the effects of ageing**. In doing this, conclusions can be drawn about the changes over time independent of unmeasurable differences in cohorts. Other strengths include the national population sampling strategy of the AusDiab cohort and the measured weight and WC at each study wave.

The potential limitation of the current study is the lack of generalisability of the included cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who attended all three waves are more select again, with higher educational attainment and a lower prevalence of chronic disease and risk factors. It is possible that a generally more healthy and health conscious population has a stronger response to population health messages, and consequently the **lesser weight gain observed here in consecutive age cohorts over time** may be greater than would be observed for the general population. However, the current observations lend support to the concept that weight gain is decreasing over time in the population, even if the AusDiab cohort represents a particularly sensitive indicator. One further potential limitation is the use of different weighing scales at AusDiab 2 and 3 compared to AusDiab1. **Although all scales were calibrated in the same way at each survey wave, differences in variability between the scales may have led to more variability in the change in weight in Period 1 than Period 2**.

The results also suggest there is no room for complacency in obesity prevention. The rates of overweight and obesity remain high, the average change in weight and WC remains an increase and there is no reduction in the **rate of** WC gain. Further, no **decrease** in the rate of weight or WC change were observed in older men. Finally, the observation that no **decrease** in rates of weight and WC change is being seen by those living in the most socially disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the social inequalities in obesity, and consequent ill health [24]. It is critical that further studies are conducted to confirm these findings and that we work to identify the causes of the observed changes, **including the differences observed in specific** population sub-groups.

In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. **While weight gain may be slowing, it does not appear to be affecting older men or those in more disadvantaged groups, and the same cannot be said for WC.**

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Figures

Figure 1. Difference in **annualised** change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

446 **Tables**

447 **Table 1** Comparison of characteristics in 1999/2000 between the included and excluded
448 population

Baseline characteristics	Included	Excluded
n	3351	7896
Sex (% men)	45	45
Age (mean, y)*	49 (11)	52 (16)
Education (% post high school)*	67	56
Area-level disadvantage (% in lowest tertile)	25	36
Born in Australia or New Zealand (%)	80	74
Never smoker (%)*	63	51
Weight (mean, kg)	76 (16)	78 (17)
Waist circumference (mean, cm)	89 (13)	92 (14)
Energy intake (mean, kj/day)	8225 (3112)	8137 (3566)
TV viewing time (mean, minutes/week)	703 (512)	829 (613)
Exercise Time (mean, minutes/week)	283 (329)	269 (332)
Diabetes (%)*	4.9	10.1
Coronary heart disease (%)*	2	5
Hypertension (%)	23	29
High blood cholesterol (%)	26	25

449 Notes: data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 2 Characteristics of the cohort in 1999/2000 and 2005

Cross-sectional characteristics	**2000**	**2005**
Age (mean, y)*	49.3 (11.1)	54.3 (11.1)
Weight (mean, kg)	76.2 (15.6)	77.9 (16.3)
Waist circumference (mean, cm)	89.4 (13.4)	91.6 (13.6)
Smoking status (% never)	63	61
Diabetes (%)	4.9	6.4
Exercise time (mean, minutes/week)*	283 (330)	306 (338)
TV time (mean, minutes/week)*	703 (512)	764 (539)
Energy intake (mean, kj/day)*	8225 (3112)	7681 (2998)
Changes during follow-up	**Period 1**	**Period 2**
Weight change (mean, kg)	1.7 (5.2)	0.9 (6.1)
Waist circumference change (mean, cm)	2.1 (6.2)	3.2 (6.9)
Follow-up (mean, y)*	5.0 (0.15)	6.9 (0.34)
Proportion gaining weight (%)*	64.5	56.8
Annualised weight change (mean, kg/y)*	0.34 (1.04)	0.13 (0.89)
Annualised WC change (mean, cm/y)	0.43 (1.25)	0.46 (1.00)

Notes: Data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

*Table 3 Change in Period 2 compared to Period 1 in **annualised** weight change (kg/year) (A); and waist circumference change (cm/year) (B)*

(A)

	Sample size	Annualised weight change in Period 1	Change in Period 2 compared to change in Period 1		
			Model 1	Model 2	Model 3
Total Population	3351	0.34 (0.30-0.37)	-0.11 (-0.15--0.06)*	-0.10 (-0.15--0.06)*	-0.10 (-0.15--0.06)*
Men	1503	0.29 (0.24-0.34)	-0.08 (-0.14--0.01)*	-0.07 (-0.14--0.01)*	-0.08 (-0.15--0.01)*
Women	1848	0.37 (0.32-0.42)	-0.13 (-0.20--0.07)*	-0.13 (-0.19--0.06)*	-0.13 (-0.19--0.06)*
Age<55	2311	0.46 (0.41-0.50)	-0.12 (-0.19--0.06)*	-0.12 (-0.18--0.06)*	-0.13 (-0.19--0.06)*
Age>=55	1040	0.07 (0.01-0.12)	-0.08 (-0.15--0.02)*	-0.08 (-0.15--0.01)*	-0.07 (-0.14--0.01)*
Education- secondary & trade certificate	2073	0.34 (0.30-0.39)	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*
Education- diploma & degree	1278	0.32 (0.27-0.38)	-0.07 (-0.14-0.00)	-0.07 (-0.14-0.00)	-0.06 (-0.14-0.01)
Area level disadvantage- tertile of most	1096	0.31 (0.24-0.37)	-0.01 (-0.09-0.07)	-0.01 (-0.09-0.07)	-0.01 (-0.10-0.07)

disadvantage					
Area level disadvantage-middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31--0.14)*	-0.22 (-0.31--0.14)*	-0.22 (-0.31--0.14)*
Area level disadvantage-tertile of least disadvantage	1125	0.30 (0.24-0.35)	-0.08 (-0.16--0.01)*	-0.08 (-0.15--0.00)*	-0.08 (-0.15--0.00)*
Normal weight	1342	0.4 (0.36-0.44)	-0.07 (-0.13--0.01)*	-0.07 (-0.13--0.01)*	-0.08 (-0.14--0.02)*
Overweight	1375	0.31 (0.26-0.37)	-0.12 (-0.18--0.05)*	-0.11 (-0.18--0.04)*	-0.12 (-0.19--0.05)*
Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*	-0.15 (-0.29--0.01)*
English speaking country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15--0.06)*	-0.1 (-0.15--0.05)*	-0.1 (-0.15--0.05)*
Non-English speaking country of birth	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)	-0.15 (-0.33-0.03)
Never smokers	2121	0.34 (0.29-0.38)	-0.10 (-0.15--0.04)*	-0.1 (-0.15--0.04)*	-0.10 (-0.15--0.04)*
Ex smokers	894	0.27 (0.20-0.34)	-0.15 (-0.24--0.06)*	-0.15 (-0.24--0.06)*	-0.16 (-0.25--0.07)*
Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)	0.00 (-0.20-0.19)
No chronic disease#	1944	0.42 (0.37-0.47)	-0.10 (-0.16--0.04)*	-0.10 (-0.16--0.04)*	-0.09 (-0.15--0.03)*

Chronic disease#	1407	0.25 (0.20-0.30)	-0.12 (-0.19--0.05)*	-0.11 (-0.19--0.04)*	-0.10 (-0.17--0.02)*

(B)

	Sample size	Annualised WC change in Period 1	Model 1	Model 2	Model 3
Total Population	3351	0.43 (0.39-0.48)	0.07 (0.02-0.12)*	0.07 (0.02-0.13)*	0.07 (0.01-0.12)*
Men	1503	0.32 (0.26-0.38)	0.13 (0.05-0.20)*	0.13 (0.06-0.21)*	0.12 (0.05-0.20)*
Women	1848	0.53 (0.47-0.59)	0.02 (-0.06-0.10)	0.03 (-0.05-0.11)	0.02 (-0.05-0.10)
Age<55	2311	0.50 (0.45-0.55)	0.05 (-0.03-0.12)	0.05 (-0.02-0.13)	0.05 (-0.03-0.12)
Age>=55	1040	0.28 (0.21-0.35)	0.10 (0.02-0.18)*	0.10 (0.02-0.19)*	0.10 (0.02-0.18)*
Education- secondary & trade certificate	2073	0.44 (0.39-0.49)	0.09 (0.02-0.15)*	0.09 (0.02-0.16)*	0.08 (0.01-0.15)*
Education- diploma & degree	1278	0.43 (0.36-0.50)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)
Area level disadvantage- tertile of most disadvantage	1096	0.41 (0.34-0.49)	0.13 (0.04-0.23)*	0.13 (0.04-0.23)*	0.14 (0.04-0.23)*
Area level disadvantage- middle tertile	1130	0.32 (0.24-0.40)	0.21 (0.11-0.31)*	0.22 (0.12-0.32)*	0.22 (0.12-0.32)*
Area level disadvantage- tertile of least disadvantage	1125	0.57 (0.50-0.64)	-0.14 (-0.23--0.05)*	-0.13 (-0.22--0.05)*	-0.15 (-0.23--0.06)*

Normal weight	1342	0.48 (0.42-0.54)	0.04 (-0.04-0.12)	0.04 (-0.04-0.12)	0.03 (-0.05-0.12)
Overweight	1375	0.43 (0.36-0.49)	0.08 (-0.01-0.16)	0.08 (-0.00-0.17)	0.07 (-0.02-0.15)
Obese	633	0.35 (0.24-0.46)	0.12 (-0.01-0.26)	0.13 (-0.00-0.27)	0.11 (-0.02-0.25)
English speaking country of birth	3129	0.44 (0.40-0.48)	0.06 (0.01-0.12)*	0.07 (0.01-0.13)*	0.06 (0.01-0.12)*
Non-English speaking country of birth	222	0.35 (0.18-0.52)	0.17 (-0.04-0.38)	0.18 (-0.02-0.39)	0.17 (-0.03-0.38)
Never smokers	2121	0.44 (0.39-0.49)	0.07 (0.00-0.14)*	0.07 (0.01-0.14)*	0.07 (0.00-0.14)*
Ex smokers	894	0.38 (0.30-0.46)	0.04 (-0.06-0.14)	0.04 (-0.06-0.14)	0.03 (-0.08-0.13)
Current smokers	336	0.56 (0.40-0.71)	0.17 (-0.05-0.39)	0.17 (-0.05-0.40)	0.18 (-0.04-0.41)
Chronic disease[1]	1944	0.47 (0.41-0.52)	0.06 (-0.01-0.13)	0.07 (-0.01-0.14)	0.07 (-0.01-0.14)
No chronic disease[1]	1407	0.44 (0.39-0.49)	0.08 (-0.00-0.17)	0.09 (0.00-0.17)*	0.1 (0.01-0.18)*

Model 1- adjusting for age and sex

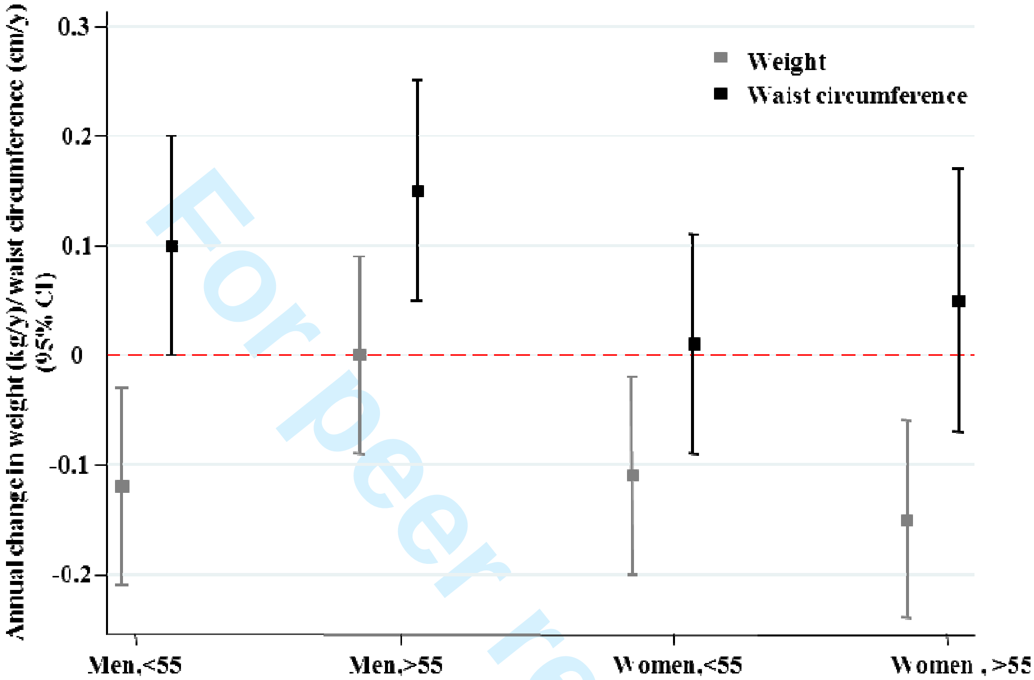
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

Model 3- additionally adjusting for baseline BMI and diabetes status

* indicates $p<0.05$

1 Chronic disease refers to any of coronary heart disease, cholesterol, hypertension, or diabetes at baseline

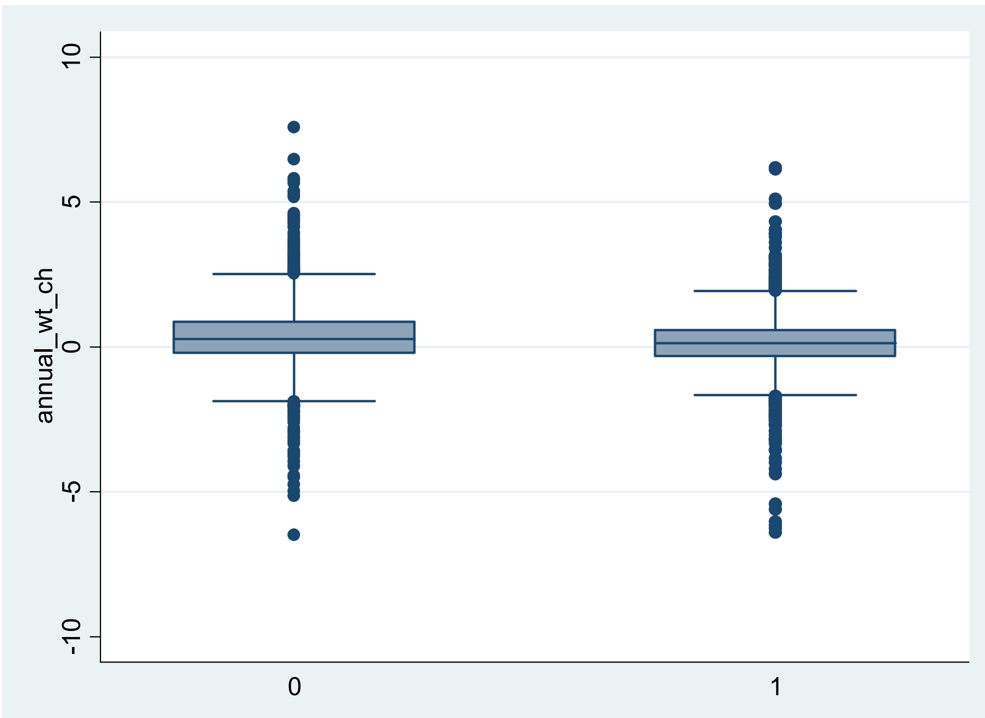
*Figure 1. Difference in **annualised** change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.*



Appendix

Figure 1 Annualised weight and waist circumference change in Period 1 and Period 2

A. **Annualised** weight change



B. **Annualised** waist circumference change

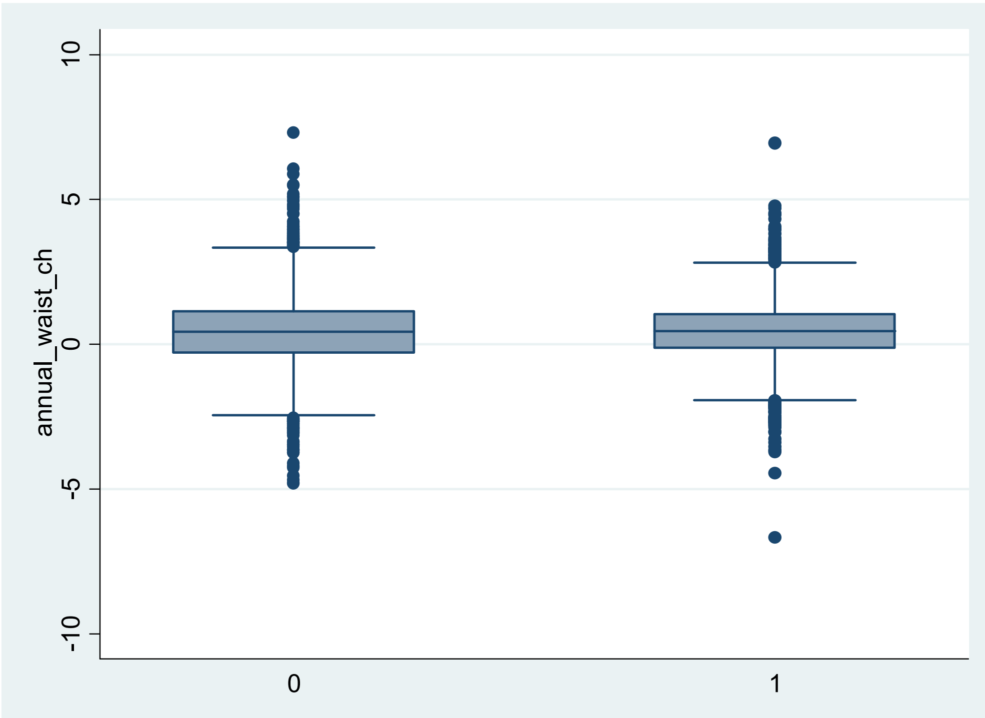


Table 1 Comparison of **annualised** weight and waist circumference change between Period 1 and Period 2 for matching age groups.

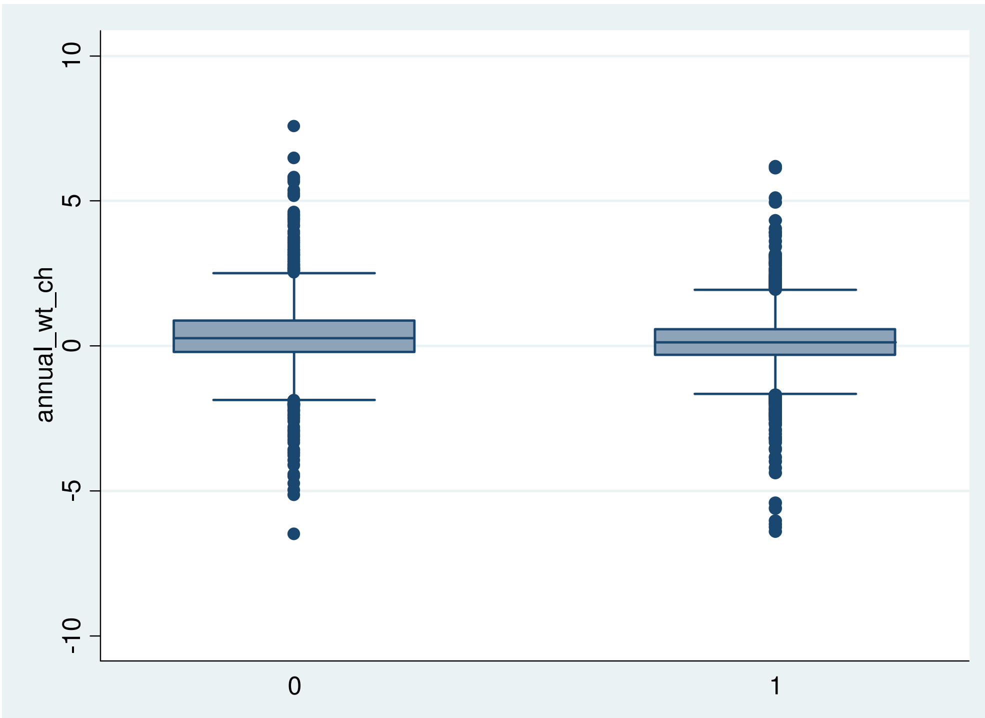
Sex	Age group	Difference in **annualised** weight change	Difference in **annualised** WC change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference ($p<0.05$)

Appendix

Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



B. Annual waist circumference change

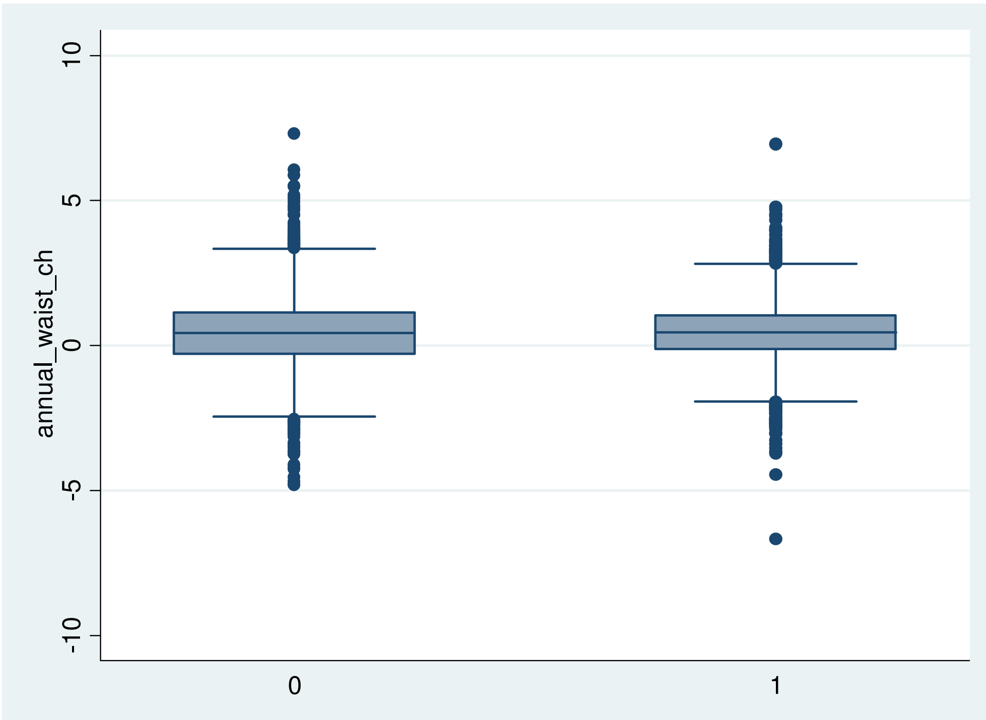


Table 1 Comparison of annual weight and waist circumference change between Period 1 and Period 2 for matching age groups.

Sex	Age group	Difference in annual weight change	Difference in annual WC change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference ($p<0.05$)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract YES
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found YES
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported YES
Objectives	3	State specific objectives, including any prespecified hypotheses YES
Methods		
Study design	4	Present key elements of study design early in the paper YES
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection YES
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up YES,
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable YES
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). YES Describe comparability of assessment methods if there is more than one group N/A
Bias	9	Describe any efforts to address potential sources of bias YES
Study size	10	Explain how the study size was arrived at YES
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why YES
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding YES
		(*b*) Describe any methods used to examine subgroups and interactions YES
		(*c*) Explain how missing data were addressed YES
		(*d*) If applicable, explain how loss to follow-up was addressed YES
		(*e*) Describe any sensitivity analyses YES

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed YES
		(b) Give reasons for non-participation at each stage NOT DONE
		(c) Consider use of a flow diagram NOT DONE
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders YES
		(b) Indicate number of participants with missing data for each variable of interest DONE IN AGGREGATE
		(c) Summarise follow-up time (eg, average and total amount) YES
Outcome data	15*	Report numbers of outcome events or summary measures over time YES
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included YES
		(*b*) Report category boundaries when continuous variables were categorized N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses YES
Discussion		
Key results	18	Summarise key results with reference to study objectives YES
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias YES
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence YES
Generalisability	21	Discuss the generalisability (external validity) of the study results YES
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based YES

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Changes in the rates of weight and waist circumference gain in Australian adults over time

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Changes in the rates of weight and waist circumference gain in Australian adults over time.

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Running title: Change in weight and waist gain over time

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ABSTRACT

Objective: To assess in a single cohort whether annual weight and waist circumference (WC) change has varied over time.

Design: Longitudinal cohort study with three surveys, 1– 1999/2000; 2– 2004/2005; 3– 2011/2012. Generalized linear mixed models with random effects were used to compare annualised weight and WC change between surveys 1 and 2 (Period 1) with that between surveys 2 and 3 (Period 2). Models were adjusted for age to analyse changes with time rather than age. Models were additionally adjusted for sex, education status, area-level socio-economic disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

Setting: The Australian Diabetes, Obesity and Lifestyle study (AusDiab)- a population-based, stratified-cluster survey of 11,247 adults aged >=25 years.

Participants: 3,351 Australian adults who attended each of three surveys and had complete measures of weight, WC and covariates.

Primary outcome measures: Weight and WC were measured at each survey. Change in weight and WC was annualised for comparison between the two Periods.

Results: Mean weight and WC increased in both Periods (0.34kg/y, 0.43cm/y Period 1; 0.13kg/y, 0.46 cm/y Period 2). Annualised weight gain in Period 2 was 0.11kg/year (95% CI 0.06–0.15) less than Period 1. Lesser annual weight gain between the two periods was not seen for those with greatest area-level socio-economic disadvantage, or in men over the age of 55. In contrast, the annualised WC increase in Period 2 was greater than Period 1 (0.07cm/year, 95% CI 0.01–0.12). The increase was greatest in males 55+ and those with greater area-level socio-economic disadvantage.

Conclusions: Between 2004/5–2011/2, Australian adults in a national study continued to gain weight, but more slowly than 1999/2000–2004/5. While weight gain may be slowing, this was not observed for older men or those in more disadvantaged groups, and the same cannot be said for WC.

Article summary

Article focus

- We aimed to assess in a single cohort whether change in weight and waist circumference has changed in recent time periods, independent of age.

Key messages

- Between 2004/5–2011/2, Australian adults in this national cohort study continued to gain weight, but more slowly than 1999/2000–2004/5.
- In contrast waist circumference gain was greater in the most recent period. Important differences were observed according to area-level socio-economic disadvantage.
- While weight gain may be slowing, this has not been observed for older men or those in more disadvantaged groups.

Strengths and limitations

- Reliably measured data in a single nationally representative cohort in recent time periods
- Analyses adjusted and matched for age for comparison between Periods to enable analysis of changes over time, rather than age

- Selection and response bias may limit the generalisability of the results to the broader Australian population

Obesity in adults has increased rapidly over the past few decades, leading to prevalence of over one quarter in many developed countries [1]. There is growing acceptance that strong preventive measures are required to stem the increasing prevalence, with a variety of approaches implemented, ranging from social marketing through whole of community interventions to regulatory strategies.

There have been some suggestions that obesity prevention interventions in children have had a positive effect, due to the observation that the prevalence of obesity is no longer increasing at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity prevalence at two time points since 1999 [4] concluded that in more developed nations a likely slowing of the rate of increase in obesity prevalence was occurring in children, with a possible turning point around 2000. However, trends in adults in this review generally appeared to be continuing to increase. Since this review, an analysis of US adults through the repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that time period in non-Hispanic white and Hispanic women, but continued increases in men and non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data suggests a continued increase in obesity prevalence in adults to 2012 [6]. However, prevalence data is driven by a range of factors, including migration, mortality and response bias. To determine whether the degree of weight gain in the population has slowed over time, a comparison of the rates of weight change is required.

We aimed to analyse whether the degree of change in weight and waist circumference (WC) over time differed in a single cohort of adults, comparing weight and WC change in the same individuals between two consecutive time periods, adjusting for age. We used the national Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared annualised change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

METHODS

Setting and Participants

The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years, recruited in 1999 -2000 (AusDiab1). Methods and response rates have been described previously[7]. Five-year follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3, respectively. For this analysis we excluded participants with missing data on weight or WC at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a final sample size of 3,351. Ethics approval was obtained from the International Diabetes Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented to participate in the study.

All study assessments followed a similar protocol [8] [7]. Data were collected by interviewer-administered questionnaires on medical history, lifestyle and health behaviour.

Outcomes

Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm. Weight was measured without shoes, excess clothing, and items in pockets by a single measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior to each set of measurements. BMI was obtained from the calculation of weight (kg) divided

by height (m^2). Annual weight change was calculated as the difference in weight between AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time between the two consecutive surveys.

Waist circumference was measured twice, halfway between the lower border of the ribs and the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the mean of the two closest measurements was calculated. Annualised WC change was calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by the follow-up time between the two consecutive surveys.

Co-factors

Data on education, country of birth, smoking and physical activity and television viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was ascertained by asking if participants had been told by a doctor or nurse that they had angina, myocardial infarction, or stroke.

Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked tobacco daily) combined [9] [7].

Education level was ascertained by asking the question "Which of these describes the highest qualification you have received?" Education was categorised as secondary only (comprising those with a secondary school qualification), diploma (comprising nursing or teaching qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor degree, post-graduate diploma or masters degree/doctorate)[10].

Area-level socio-economic disadvantage was estimated using the Index of Relative Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was

developed by the Australian Bureau of Statistics, to create a summary measure from a group of 20 variables (related to education, income, employment, family composition, housing benefits, car ownership, ethnicity, English language proficiency, residential overcrowding) displaying dimensions of social disadvantage [11]. The index is constructed so that high values reflect areas with high socio-economic status (relative advantage) and low values reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage were calculated amongst the final study sample.

Physical activity was measured via an interviewer-administered Active Australia questionnaire, which considered participation in predominantly leisure-time physical activities (including walking for transport) during the previous week [12]. Total physical activity time was calculated as the sum of the time spent walking (if continuous and for ≥10 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-intensity physical activity [13].

Self-reported television viewing time was calculated as the total time spent watching television or videos in the previous week, and is considered a reliable and valid estimate of television viewing time among adults [14].

Average daily energy intake was assessed using a self-administered food frequency questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with additional questions on food habits, portion size and consumption of alcoholic beverages. In AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential measurement error, manual blood pressure measurements were adjusted as previously described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.

Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus Optical, Tokyo, Japan) at a central laboratory [17].

Classification of diabetes status has been described elsewhere [17]. Briefly, participants were classified as having ‘known diabetes’ if they reported having doctor diagnosed diabetes and were either taking hypoglycaemic medication or had fasting plasma glucose (FPG) ≥7.0mmol/L or a 2-hour plasma glucose (PG)≥ 11.1mmol/L. Participants not reporting diabetes but with FPG≥7.0mmol/L or 2-hour PG≥ 11.1mmol/L were classified as having ‘newly diagnosed diabetes’.

Statistical analysis

Baseline characteristics (means and proportions at AusDiab1) were compared between AusDiab participants with and without complete measures at AusDiab 1, 2 and 3. Characteristics of the included population were also compared in 2000 and 2005, representing the two baseline surveys for the two weight change periods.

The difference in annualised weight and WC change in Period 1 (2000 to 2005), compared to Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear mixed models with random effects were used to analyse the association between study period on annual weight or WC change. This model includes random effects associated with both the cluster and the units of analysis (participants) to take the clustered structure of the data into account and to allow the residuals associated with the longitudinal measures on the same unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model 1), additionally adjusting for smoking, education, area level disadvantage and country of birth (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4). Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2 for change in Period 2. Adjustment for age enables the differences in weight and WC change

observed between the two Periods to be attributed to time rather than age. The association between study period and annualised weight and WC change was also analysed across sub-groups and interaction terms between study period with age or sex were analysed.

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80.

All analyses were performed in STATA (version 11.0), with statistical significance set at the 5% level.

RESULTS

The population with complete measures was similar to the total AusDiab cohort with respect to sex and weight, but was younger, with higher educational attainment, and a higher prevalence of never smoking (Table 1). The population with complete measures also had a lower prevalence of chronic disease. There was no appreciable difference between the two groups for weight change in Period 1 after adjustment for differences in age and sex.

(Table 1 here)

Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to being five years older, the population had a higher prevalence of diabetes (predominantly type 2). In both periods the average change in weight and WC was a gain. In Period 2, a smaller proportion of the population gained weight and annualised weight gain was less, at 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser weight change across the entire distribution of weight change in Period 2, with minimal difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile of weight change (Appendix Figure 1A). For WC, there was no difference in the crude annualised change between the two periods (Table 2). In contrast to weight change, this resulted from both a smaller gain in those whose WC increased and a smaller loss in those whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

(Table 2 here)

Comparison of the crude annualised weight change for matching 10-year age-groups in Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups, although these differences were only significant for men aged 35–44, and women 45–54 and

65–74 (Table 3). Comparison of the crude annualised WC change for matching age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64; Table 3).

(Table 3 here)

The difference in annualised weight and WC change in Period 2, compared to Period 1, was assessed using linear regression analysis (Table 4). In Period 2, annualised weight gain was 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after further adjustment for smoking status, education status, ethnicity, area-level socio-economic disadvantage, baseline BMI and diabetes status (Table 4A), nor after adjustment for TV time, exercise time and energy intake (results not shown).

Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 4A), with suggestions of a greater difference over time in women, and those aged under 55 years (although no interaction tests on these factors were significant). Annualised weight gain in Period 2 was non-significantly less than in Period 1 for those with high educational attainment (borderline significant), obesity, and those from a non-English speaking background. No difference in annualised weight gain between the two periods was observed for those in the tertile of greatest area-level socio-economic disadvantage, nor for current smokers.

In Period 2, annualised WC gain was 0.07 cm/year more than in Period 1 (Table 4B). This did not alter substantially after further adjustment for smoking status, education status, area-level socio-economic disadvantage, ethnicity, baseline BMI and diabetes status (Table 4B), nor after adjustment for TV time, exercise time and energy intake (results not shown).

In stratified analyses no difference in annualised WC gain between the two periods was observed for women, those aged<55 years, those in the highest education group, those with normal weight nor ex-smokers. Annualised WC gain was less in Period 2 than Period 1 for those in the tertile of least area-level socio-economic disadvantage (-0.14cm/year 95%CI -.05, -0.23).

(Table 4 here)

For both weight and WC, there was an apparent combined sex and age effect, such that older men had the least favourable changes over time (Figure 1).

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80. No differences in results were seen.

DISCUSSION

In this analysis of a single cohort of Australian adults, weight and WC increased in the most recent period in all population sub-groups examined. Age-adjusted annualised weight gain between 2005–2012 was less than between 1999/2000–2005, but annualised WC gain was greater. Lesser weight gain over time was not seen in older men or those with greatest area-level socio-economic disadvantage.

The lack of difference in weight and WC change between the two periods observed for current smokers, those from a non-English speaking background and those with obesity, is likely to reflect small sample sizes in these groups. In general, adjustment for covariates had little effect on the observed associations between study period and weight and WC change. As time spent watching TV, exercise and energy intake might be expected to be mediating much of the observed changes, we had expected an observable reduction in the difference between study periods after adjustment for these factors. The lack of impact after adjustment likely reflects that they are relatively blunt instruments to detect small changes in behaviour over time. The self-reported nature of these behavioural questionnaires is associated with both differential and non-differential error [18] [19]. While validated, the FFQ is has a limited list of foods and is affected by the inability of individuals to accurately report their food intake retrospectively over a long period of time [20]. Further the Active Australia questionnaire only refers to leisure time activity and TV watching is only one component of sitting time.

The general observation that weight gain may be lessening over time supports the cross-sectional time series observations of a plateau in the prevalence of obesity and rate of change in BMI [4]. However, these results also suggest that the general observations do not tell the whole story, with large differences between different population subgroups, and a contrasting observation for waist circumference. The sex differences observed here are similar to the cross-sectional trends reported for American adults for whom a clear plateau in obesity prevalence has been observed for women but not men [5]. The differences we observed according to level of area-level socio-economic disadvantage also reflect findings from the review of obesity trends in which the levelling off of obesity was generally more pronounced in groups with higher socio-economic position [4]. It will be important to do a similar analysis in a longitudinal children's cohort, as their experience is likely to differ from that of adults. Children have been exposed to a wide range of obesity prevention interventions, particularly in schools, in countries such as Australia and cross-sectional trends clearly suggest a plateauing in the prevalence of obesity in children [4].

The observation that rates of WC change may be continuing to increase even as rates of weight change decrease may reflect prior findings using the NHANES data that WC is increasing to a greater extent than expected from changes in weight [21] [22]. While we observed changes in weight and WC to be highly correlated these results combined suggest a preferential increase in abdominal adiposity over time, which is thought to be associated with greater risk of cardio-metabolic outcomes [23]. The potential implication that current bodyweight trends are leading a more metabolically active obesity, with increased risks for outcomes such as diabetes, hypertension and cardiovascular disease warrants further investigation.

The key strength of the current study is that for the first time it addresses this important question through an analysis of the same cohort of adults over two distinct but recent time periods, independent of the effects of ageing. In doing this, conclusions can be drawn about the changes over time independent of unmeasurable differences in cohorts. Other strengths include the national population sampling strategy of the AusDiab cohort and the measured weight and WC at each study wave.

The potential limitation of the current study is the lack of generalisability of the included cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who attended all three waves are more select again, with higher educational attainment and a lower prevalence of chronic disease and risk factors. It is possible that a generally more healthy and health conscious population has a stronger response to population health messages, and consequently the lesser weight gain observed here in consecutive age cohorts over time may be greater than would be observed for the general population. However, the current observations lend support to the concept that weight gain is decreasing over time in the population, even if the AusDiab cohort represents a particularly sensitive indicator. One further potential limitation is the use of different weighing scales at AusDiab 2 and 3 compared to AusDiab1. Although all scales were calibrated in the same way at each survey wave, differences in variability between the scales may have led to more variability in the change in weight in Period 1 than Period 2.

The results also suggest there is no room for complacency in obesity prevention. The rates of overweight and obesity remain high, the average change in weight and WC remains an increase and there is no reduction in the rate of WC gain. Further, no decrease in the rate of weight or WC change were observed in older men. Finally, the observation that no decrease in rates of weight and WC change is being seen by those living in the most socially disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the social inequalities in obesity, and consequent ill health [24]. It is critical that further studies are conducted to confirm these findings and that we work to identify the causes of the observed changes, including the differences observed in specific population sub-groups.

In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While weight gain may be slowing, it does not appear to be affecting older men or those in more disadvantaged groups, and the same cannot be said for WC.

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Data sharing

Extra data is available by emailing A Peeters at anna.peeters@bakeridi.edu.au

Authorship statement

AP conceived of the article, executed the analysis and writing of the article and is guarantor for the article. JS, DM and KB contributed to the ideas included within and writing of the article, and provision of data. PZ contributed to the writing of the article and provision of data.

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Competing Interests

None

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Figures

Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

Tables

Table 1 Comparison of characteristics in 1999/2000 between the included and excluded population

Baseline characteristics	Included	Excluded
n	3351	7896
Sex (% men)	45	45
Age (mean, y)*	49 (11)	52 (16)
Education (% post high school)*	67	56
Area-level disadvantage (% in lowest tertile)	25	36
Born in Australia or New Zealand (%)	80	74
Never smoker (%)*	63	51
Weight (mean, kg)	76 (16)	78 (17)
Waist circumference (mean, cm)	89 (13)	92 (14)
Energy intake (mean, kj/day)	8225 (3112)	8137 (3566)
TV viewing time (mean, minutes/week)	703 (512)	829 (613)
Exercise Time (mean, minutes/week)	283 (329)	269 (332)
Diabetes (%)*	4.9	10.1
Coronary heart disease (%)*	2	5
Hypertension (%)	23	29
High blood cholesterol (%)	26	25

Notes: data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 2 Characteristics of the cohort in 1999/2000 and 2005

Cross-sectional characteristics	2000	2005
Age (mean, y)*	49.3 (11.1)	54.3 (11.1)
Weight (mean, kg)	76.2 (15.6)	77.9 (16.3)
Waist circumference (mean, cm)	89.4 (13.4)	91.6 (13.6)
Smoking status (% never)	63	61
Diabetes (%)	4.9	6.4
Exercise time (mean, minutes/week)*	283 (330)	306 (338)
TV time (mean, minutes/week)*	703 (512)	764 (539)
Energy intake (mean, kj/day)*	8225 (3112)	7681 (2998)
Changes during follow-up	**Period 1**	**Period 2**
Weight change (mean, kg)	1.7 (5.2)	0.9 (6.1)
Waist circumference change (mean, cm)	2.1 (6.2)	3.2 (6.9)
Follow-up (mean, y)*	5.0 (0.15)	6.9 (0.34)
Proportion gaining weight (%)*	64.5	56.8
Annualised weight change (mean, kg/y)*	0.34 (1.04)	0.13 (0.89)
Annualised WC change (mean, cm/y)	0.43 (1.25)	0.46 (1.00)

Notes: Data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 3 Comparison of annualised weight and waist circumference change between Period 1 and Period 2 for matching age groups.

Sex	Age group	Difference in annualised weight change	Difference in annualised waist circumference change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference (p<0.05)

Table 4 Difference in annualised change in weight (kg/year) (A) and waist circumference (cm/year) (B) in Period 2 compared to Period 1

(A)

	Sample size	Annualised weight change in Period 1	Difference in annualised change in Period 2 compared to change in Period 1		
			Model 1	Model 2	Model 3
Total Population	3351	0.34 (0.30-0.37)	-0.11 (-0.15--0.06)*	-0.10 (-0.15--0.06)*	-0.10 (-0.15--0.06)*
Men	1503	0.29 (0.24-0.34)	-0.08 (-0.14--0.01)*	-0.07 (-0.14--0.01)*	-0.08 (-0.15--0.01)*
Women	1848	0.37 (0.32-0.42)	-0.13 (-0.20--0.07)*	-0.13 (-0.19--0.06)*	-0.13 (-0.19--0.06)*
Age<55	2311	0.46 (0.41-0.50)	-0.12 (-0.19--0.06)*	-0.12 (-0.18--0.06)*	-0.13 (-0.19--0.06)*
Age>=55	1040	0.07 (0.01-0.12)	-0.08 (-0.15--0.02)*	-0.08 (-0.15--0.01)*	-0.07 (-0.14--0.01)*
Education- secondary & trade certificate	2073	0.34 (0.30-0.39)	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*
Education- diploma & degree	1278	0.32 (0.27-0.38)	-0.07 (-0.14-0.00)	-0.07 (-0.14-0.00)	-0.06 (-0.14-0.01)
Area level disadvantage- tertile of most disadvantage	1096	0.31 (0.24-0.37)	-0.01 (-0.09-0.07)	-0.01 (-0.09-0.07)	-0.01 (-0.10-0.07)
Area level disadvantage- middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31--0.14)*	-0.22 (-0.31--0.14)*	-0.22 (-0.31--0.14)*
Area level disadvantage- tertile of least	1125	0.30 (0.24-0.35)	-0.08 (-0.16--0.01)*	-0.08 (-0.15--0.00)*	-0.08 (-0.15--0.00)*

disadvantage					
Normal weight	1342	0.4 (0.36-0.44)	-0.07 (-0.13--0.01)*	-0.07 (-0.13--0.01)*	-0.08 (-0.14--0.02)*
Overweight	1375	0.31 (0.26-0.37)	-0.12 (-0.18--0.05)*	-0.11 (-0.18--0.04)*	-0.12 (-0.19--0.05)*
Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*	-0.15 (-0.29--0.01)*
English speaking country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15--0.06)*	-0.1 (-0.15--0.05)*	-0.1 (-0.15--0.05)*
Non-English speaking country of birth	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)	-0.15 (-0.33-0.03)
Never smokers	2121	0.34 (0.29-0.38)	-0.10 (-0.15--0.04)*	-0.1 (-0.15--0.04)*	-0.10 (-0.15--0.04)*
Ex smokers	894	0.27 (0.20-0.34)	-0.15 (-0.24--0.06)*	-0.15 (-0.24--0.06)*	-0.16 (-0.25--0.07)*
Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)	0.00 (-0.20-0.19)
No chronic disease#	1944	0.42 (0.37-0.47)	-0.10 (-0.16--0.04)*	-0.10 (-0.16--0.04)*	-0.09 (-0.15--0.03)*
Chronic disease#	1407	0.25 (0.20-0.30)	-0.12 (-0.19--0.05)*	-0.11 (-0.19--0.04)*	-0.10 (-0.17--0.02)*

(B)

	Sample size	Annualised WC change in Period 1	Difference in annualised change in Period 2 compared to change in Period 1		
			Model 1	Model 2	Model 3
Total Population	3351	0.43 (0.39-0.48)	0.07 (0.02-0.12)*	0.07 (0.02-0.13)*	0.07 (0.01-0.12)*
Men	1503	0.32 (0.26-0.38)	0.13 (0.05-0.20)*	0.13 (0.06-0.21)*	0.12 (0.05-0.20)*

Women	1848	0.53 (0.47-0.59)	0.02 (-0.06-0.10)	0.03 (-0.05-0.11)	0.02 (-0.05-0.10)
Age<55	2311	0.50 (0.45-0.55)	0.05 (-0.03-0.12)	0.05 (-0.02-0.13)	0.05 (-0.03-0.12)
Age>=55	1040	0.28 (0.21-0.35)	0.10 (0.02-0.18)*	0.10 (0.02-0.19)*	0.10 (0.02-0.18)*
Education- secondary & trade certificate	2073	0.44 (0.39-0.49)	0.09 (0.02-0.15)*	0.09 (0.02-0.16)*	0.08 (0.01-0.15)*
Education- diploma & degree	1278	0.43 (0.36-0.50)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)
Area level disadvantage- tertile of most disadvantage	1096	0.41 (0.34-0.49)	0.13 (0.04-0.23)*	0.13 (0.04-0.23)*	0.14 (0.04-0.23)*
Area level disadvantage- middle tertile	1130	0.32 (0.24-0.40)	0.21 (0.11-0.31)*	0.22 (0.12-0.32)*	0.22 (0.12-0.32)*
Area level disadvantage- tertile of least disadvantage	1125	0.57 (0.50-0.64)	-0.14 (-0.23--0.05)*	-0.13 (-0.22--0.05)*	-0.15 (-0.23--0.06)*
Normal weight	1342	0.48 (0.42-0.54)	0.04 (-0.04-0.12)	0.04 (-0.04-0.12)	0.03 (-0.05-0.12)
Overweight	1375	0.43 (0.36-0.49)	0.08 (-0.01-0.16)	0.08 (-0.00-0.17)	0.07 (-0.02-0.15)
Obese	633	0.35 (0.24-0.46)	0.12 (-0.01-0.26)	0.13 (-0.00-0.27)	0.11 (-0.02-0.25)
English speaking country of birth	3129	0.44 (0.40-0.48)	0.06 (0.01-0.12)*	0.07 (0.01-0.13)*	0.06 (0.01-0.12)*
Non-English speaking country of birth	222	0.35 (0.18-0.52)	0.17 (-0.04-0.38)	0.18 (-0.02-0.39)	0.17 (-0.03-0.38)
Never smokers	2121	0.44 (0.39-0.49)	0.07 (0.00-0.14)*	0.07 (0.01-0.14)*	0.07 (0.00-0.14)*

Ex smokers	894	0.38 (0.30-0.46)	0.04 (-0.06-0.14)	0.04 (-0.06-0.14)	0.03 (-0.08-0.13)
Current smokers	336	0.56 (0.40-0.71)	0.17 (-0.05-0.39)	0.17 (-0.05-0.40)	0.18 (-0.04-0.41)
Chronic disease[1]	1944	0.47 (0.41-0.52)	0.06 (-0.01-0.13)	0.07 (-0.01-0.14)	0.07 (-0.01-0.14)
No chronic disease[1]	1407	0.44 (0.39-0.49)	0.08 (-0.00-0.17)	0.09 (0.00-0.17)*	0.1 (0.01-0.18)*

Model 1- adjusting for age and sex

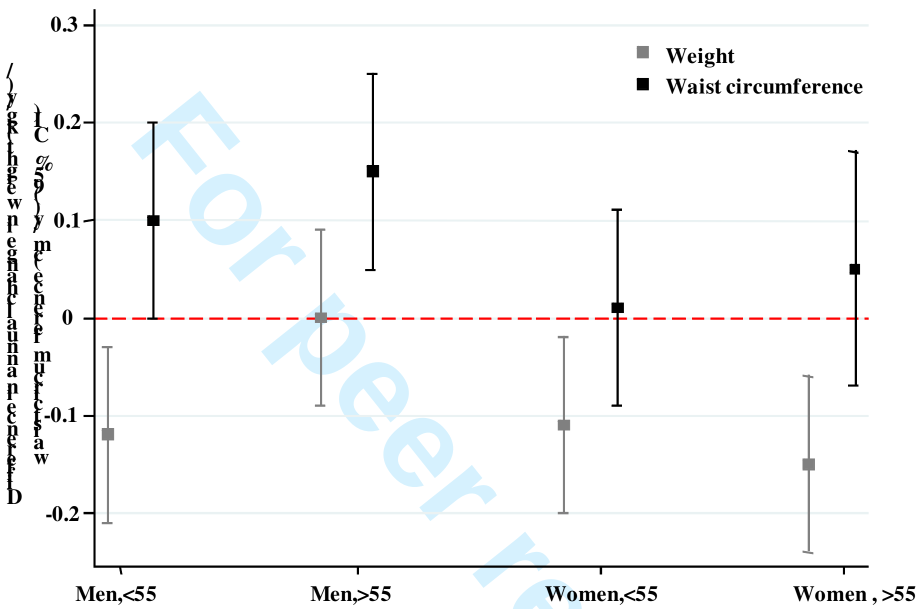
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

Model 3- additionally adjusting for baseline BMI and diabetes status

* indicates p<0.05

1 Chronic disease refers to any of coronary heart disease, cholesterol, hypertension, or diabetes at baseline

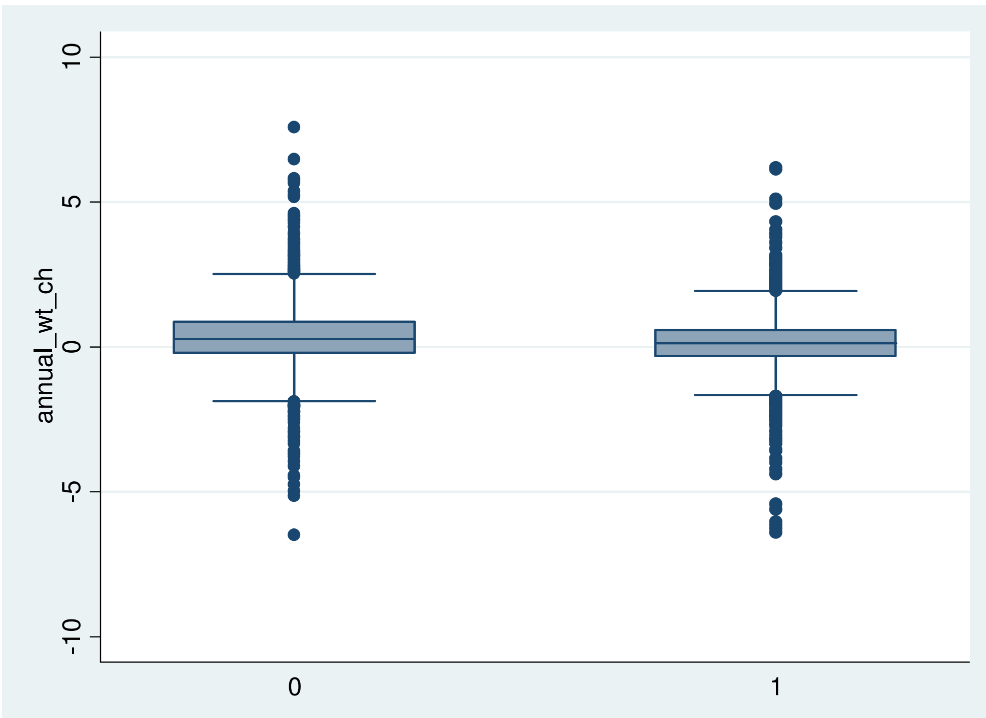
Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.



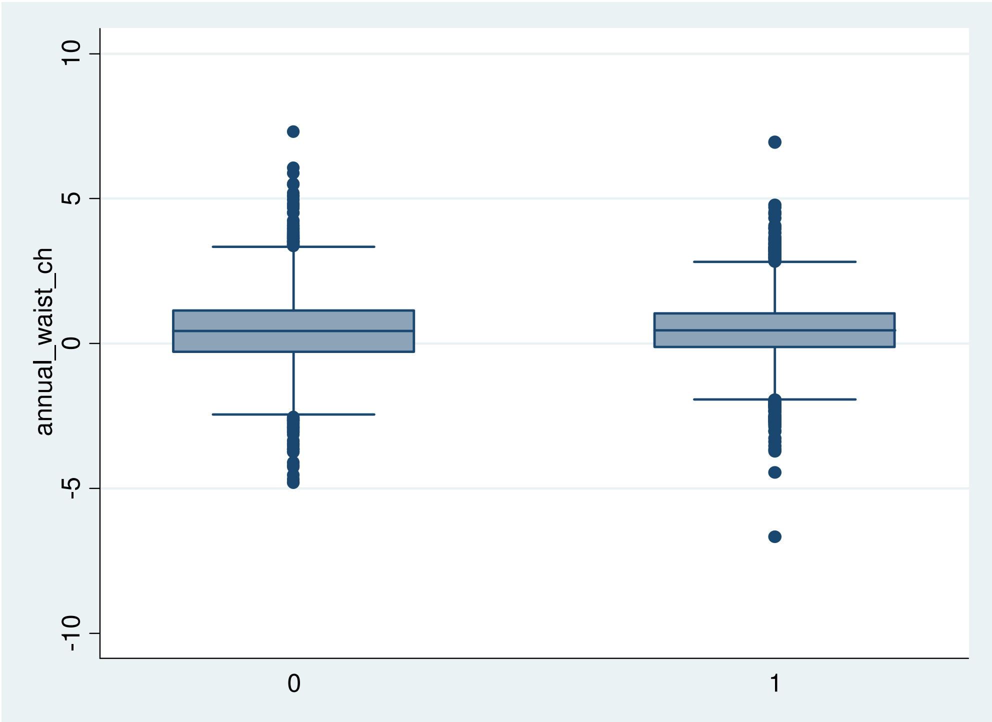
Appendix

Figure 1 Annualised weight and waist circumference change in Period 1 and Period 2

A. Annualised weight change



B. Annualised waist circumference change



Changes in the rates of weight and waist circumference gain in Australian adults over time.

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Authorship statement

AP conceived of the article, executed the analysis and writing of the article and is guarantor for the article. JS, DM and KB contributed to the ideas included within and writing of the article, and provision of data. PZ contributed to the writing of the article and provision of data.

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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.

Article summary

Article focus

- We aimed to assess in a single cohort whether change in weight and waist circumference has changed in recent time periods, independent of age.

Key messages

- Between 2004/5–2011/2, Australian adults in this national cohort study continued to gain weight, but more slowly than 1999/2000–2004/5.
- In contrast waist circumference gain was greater in the most recent period. Important differences were observed according to area-level socio-economic disadvantage.
- While weight gain may be slowing, this has not been observed for older men or those in more disadvantaged groups.

Strengths and limitations

- Reliably measured data in a single nationally representative cohort in recent time periods
- Analyses adjusted and matched for age for comparison between Periods to enable analysis of changes over time, rather than age
- Selection and response bias may limit the generalisability of the results to the broader Australian population

ABSTRACT

Objective: To assess in a single cohort whether annual weight and waist circumference (WC) change has varied over time.

Design: Longitudinal cohort study with three surveys, 1– 1999/2000; 2– 2004/2005; 3– 2011/2012. Generalized linear mixed models with random effects were used to compare annualised weight and WC change between surveys 1 and 2 (Period 1) with that between surveys 2 and 3 (Period 2). Models were adjusted for age to analyse changes with time rather than age. Models were additionally adjusted for sex, education status, area-level socio-economic disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

Setting: The Australian Diabetes, Obesity and Lifestyle study (AusDiab)- a population-based, stratified-cluster survey of 11,247 adults aged >=25 years.

Participants: 3,351 Australian adults who attended each of three surveys and had complete measures of weight, WC and covariates.

Primary outcome measures: Weight and WC were measured at each survey. Change in weight and WC was annualised for comparison between the two Periods.

Results: Mean weight and WC increased in both Periods (0.34kg/y, 0.43cm/y Period 1; 0.13kg/y, 0.46 cm/y Period 2). Annualised weight gain in Period 2 was 0.11kg/year (95% CI 0.06–0.15) less than Period 1. Lesser annual weight gain between the two periods was not seen for those with greatest area-level socio-economic disadvantage, or in men over the age of 55. In contrast, the annualised WC increase in Period 2 was greater than Period 1 (0.07cm/year, 95% CI 0.01–0.12). The increase was greatest in males 55+ and those with greater area-level socio-economic disadvantage.

Conclusions: Between 2004/5–2011/2, Australian adults in a national study continued to gain weight, but more slowly than 1999/2000–2004/5. While weight gain may be slowing, this was not observed for older men or those in more disadvantaged groups, and the same cannot be said for WC.

Obesity in adults has increased rapidly over the past few decades, leading to prevalence of over one quarter in many developed countries [1]. There is growing acceptance that strong preventive measures are required to stem the increasing prevalence, with a variety of approaches implemented, ranging from social marketing through whole of community interventions to regulatory strategies.

There have been some suggestions that obesity prevention interventions in children have had a positive effect, due to the observation that the prevalence of obesity is no longer increasing at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity prevalence at two time points since 1999 [4] concluded that in more developed nations a likely slowing of the rate of increase in obesity prevalence was occurring in children, with a possible turning point around 2000. However, trends in adults in this review generally appeared to be continuing to increase. Since this review, an analysis of US adults through the repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that time period in non-Hispanic white and Hispanic women, but continued increases in men and non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data suggests a continued increase in obesity prevalence in adults to 2012 [6]. However, prevalence data is driven by a range of factors, including migration, mortality and response bias. To determine whether the degree of weight gain in the population has slowed over time, a comparison of the rates of weight change is required.

We aimed to analyse whether the degree of change in weight and waist circumference (WC) over time differed in a single cohort of adults, comparing weight and WC change in the same individuals between two consecutive time periods, adjusting for age. We used the national Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared annualised change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

METHODS

Setting and Participants

The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based, stratified-cluster survey of 11, 247 adults aged >=25 years, recruited in 1999 -2000 (AusDiab1). Methods and response rates have been described previously[7]. Five-year follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3, respectively. For this analysis we excluded participants with missing data on weight or WC at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a final sample size of 3,351. Ethics approval was obtained from the International Diabetes Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented to participate in the study.

All study assessments followed a similar protocol [8] [7]. Data were collected by interviewer-administered questionnaires on medical history, lifestyle and health behaviour.

Outcomes

Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm. Weight was measured without shoes, excess clothing, and items in pockets by a single measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior to each set of measurements. BMI was obtained from the calculation of weight (kg) divided

by height (m^2). Annual weight change was calculated as the difference in weight between AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time between the two consecutive surveys.

Waist circumference was measured twice, halfway between the lower border of the ribs and the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the mean of the two closest measurements was calculated. Annualised WC change was calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by the follow-up time between the two consecutive surveys.

Co-factors

Data on education, country of birth, smoking and physical activity and television viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was ascertained by asking if participants had been told by a doctor or nurse that they had angina, myocardial infarction, or stroke.

Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked tobacco daily) combined [9] [7].

Education level was ascertained by asking the question "Which of these describes the highest qualification you have received?" Education was categorised as secondary only (comprising those with a secondary school qualification), diploma (comprising nursing or teaching qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor degree, post-graduate diploma or masters degree/doctorate)[10].

Area-level socio-economic disadvantage was estimated using the Index of Relative Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was

developed by the Australian Bureau of Statistics, to create a summary measure from a group of 20 variables (related to education, income, employment, family composition, housing benefits, car ownership, ethnicity, English language proficiency, residential overcrowding) displaying dimensions of social disadvantage [11]. The index is constructed so that high values reflect areas with high socio-economic status (relative advantage) and low values reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage were calculated amongst the final study sample.

Physical activity was measured via an interviewer-administered Active Australia questionnaire, which considered participation in predominantly leisure-time physical activities (including walking for transport) during the previous week [12]. Total physical activity time was calculated as the sum of the time spent walking (if continuous and for ≥10 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-intensity physical activity [13].

Self-reported television viewing time was calculated as the total time spent watching television or videos in the previous week, and is considered a reliable and valid estimate of television viewing time among adults [14].

Average daily energy intake was assessed using a self-administered food frequency questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with additional questions on food habits, portion size and consumption of alcoholic beverages. In AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential measurement error, manual blood pressure measurements were adjusted as previously described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.

Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus Optical, Tokyo, Japan) at a central laboratory [17].

Classification of diabetes status has been described elsewhere [17]. Briefly, participants were classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and were either taking hypoglycaemic medication or had fasting plasma glucose (FPG) $\geq$7.0mmol/L or a 2-hour plasma glucose (PG)$\geq$ 11.1mmol/L. Participants not reporting diabetes but with FPG$\geq$7.0mmol/L or 2-hour PG$\geq$ 11.1mmol/L were classified as having 'newly diagnosed diabetes'.

Statistical analysis

Baseline characteristics (means and proportions at AusDiab1) were compared between AusDiab participants with and without complete measures at AusDiab 1, 2 and 3. Characteristics of the included population were also compared in 2000 and 2005, representing the two baseline surveys for the two weight change periods.

The difference in annualised weight and WC change in Period 1 (2000 to 2005), compared to Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear mixed models with random effects were used to analyse the association between study period on annual weight or WC change. This model includes random effects associated with both the cluster and the units of analysis (participants) to take the clustered structure of the data into account and to allow the residuals associated with the longitudinal measures on the same unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model 1), additionally adjusting for smoking, education, area level disadvantage and country of birth (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4). Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2 for change in Period 2. Adjustment for age enables the differences in weight and WC change

observed between the two Periods to be attributed to time rather than age. The association between study period and annualised weight and WC change was also analysed across sub-groups and interaction terms between study period with age or sex were analysed.

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80.

All analyses were performed in STATA (version 11.0), with statistical significance set at the 5% level.

RESULTS

The population with complete measures was similar to the total AusDiab cohort with respect to sex and weight, but was younger, with higher educational attainment, and a higher prevalence of never smoking (Table 1). The population with complete measures also had a lower prevalence of chronic disease. There was no appreciable difference between the two groups for weight change in Period 1 after adjustment for differences in age and sex.

(Table 1 here)

Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to being five years older, the population had a higher prevalence of diabetes (predominantly type 2). In both periods the average change in weight and WC was a gain. In Period 2, a smaller proportion of the population gained weight and annualised weight gain was less, at 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser weight change across the entire distribution of weight change in Period 2, with minimal difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile of weight change (Appendix Figure 1A). For WC, there was no difference in the crude annualised change between the two periods (Table 2). In contrast to weight change, this resulted from both a smaller gain in those whose WC increased and a smaller loss in those whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

(Table 2 here)

Comparison of the crude annualised weight change for matching 10-year age-groups in Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups, although these differences were only significant for men aged 35–44, and women 45–54 and

65–74 (Table 3). Comparison of the crude annualised WC change for matching age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64; Table 3).

(Table 3 here)

The difference in annualised weight and WC change in Period 2, compared to Period 1, was assessed using linear regression analysis (Table 4). In Period 2, annualised weight gain was 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after further adjustment for smoking status, education status, ethnicity, area-level socio-economic disadvantage, baseline BMI and diabetes status (Table 4A), nor after adjustment for TV time, exercise time and energy intake (results not shown).

Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 4A), with suggestions of a greater difference over time in women, and those aged under 55 years (although no interaction tests on these factors were significant). Annualised weight gain in Period 2 was non-significantly less than in Period 1 for those with high educational attainment (borderline significant), obesity, and those from a non-English speaking background. No difference in annualised weight gain between the two periods was observed for those in the tertile of greatest area-level socio-economic disadvantage, nor for current smokers.

In Period 2, annualised WC gain was 0.07 cm/year more than in Period 1 (Table 4B). This did not alter substantially after further adjustment for smoking status, education status, area-level socio-economic disadvantage, ethnicity, baseline BMI and diabetes status (Table 4B), nor after adjustment for TV time, exercise time and energy intake (results not shown).

In stratified analyses no difference in annualised WC gain between the two periods was observed for women, those aged<55 years, those in the highest education group, those with normal weight nor ex-smokers. Annualised WC gain was less in Period 2 than Period 1 for those in the tertile of least area-level socio-economic disadvantage (-0.14cm/year 95%CI -.05, -0.23).

(Table 4 here)

For both weight and WC, there was an apparent combined sex and age effect, such that older men had the least favourable changes over time (Figure 1).

The primary analyses were repeated after excluding the few participants with annual weight change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping age group of 30–80. No differences in results were seen.

DISCUSSION

In this analysis of a single cohort of Australian adults, weight and WC increased in the most recent period in all population sub-groups examined. Age-adjusted annualised weight gain between 2005–2012 was less than between 1999/2000–2005, but annualised WC gain was greater. Lesser weight gain over time was not seen in older men or those with greatest area-level socio-economic disadvantage.

The lack of difference in weight and WC change between the two periods observed for current smokers, those from a non-English speaking background and those with obesity, is likely to reflect small sample sizes in these groups. In general, adjustment for covariates had little effect on the observed associations between study period and weight and WC change. As time spent watching TV, exercise and energy intake might be expected to be mediating much of the observed changes, we had expected an observable reduction in the difference between study periods after adjustment for these factors. The lack of impact after adjustment likely reflects that they are relatively blunt instruments to detect small changes in behaviour over time. The self-reported nature of these behavioural questionnaires is associated with both differential and non-differential error [18] [19]. While validated, the FFQ is has a limited list of foods and is affected by the inability of individuals to accurately report their food intake retrospectively over a long period of time [20]. Further the Active Australia questionnaire only refers to leisure time activity and TV watching is only one component of sitting time.

The general observation that weight gain may be lessening over time supports the cross-sectional time series observations of a plateau in the prevalence of obesity and rate of change in BMI [4]. However, these results also suggest that the general observations do not tell the whole story, with large differences between different population subgroups, and a contrasting observation for waist circumference. The sex differences observed here are similar to the cross-sectional trends reported for American adults for whom a clear plateau in obesity prevalence has been observed for women but not men [5]. The differences we observed according to level of area-level socio-economic disadvantage also reflect findings from the review of obesity trends in which the levelling off of obesity was generally more pronounced in groups with higher socio-economic position [4]. It will be important to do a similar analysis in a longitudinal children's cohort, as their experience is likely to differ from that of adults. Children have been exposed to a wide range of obesity prevention interventions, 316 particularly in schools, in countries such as Australia and cross-sectional trends clearly suggest a plateauing in the prevalence of obesity in children [4].

318 The observation that rates of WC change may be continuing to increase even as rates of weight change decrease may reflect prior findings using the NHANES data that WC is increasing to a greater extent than expected from changes in weight [21] [22]. While we observed changes in weight and WC to be highly correlated these results combined suggest a preferential increase in abdominal adiposity over time, which is thought to be associated with greater risk of cardio-metabolic outcomes [23]. The potential implication that current bodyweight trends are leading a more metabolically active obesity, with increased risks for outcomes such as diabetes, hypertension and cardiovascular disease warrants further investigation.

327 The key strength of the current study is that for the first time it addresses this important question through an analysis of the same cohort of adults over two distinct but recent time periods, independent of the effects of ageing. In doing this, conclusions can be drawn about the changes over time independent of unmeasurable differences in cohorts. Other strengths include the national population sampling strategy of the AusDiab cohort and the measured weight and WC at each study wave.

333 The potential limitation of the current study is the lack of generalisability of the included cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who attended all three waves are more select again, with higher educational attainment and a lower prevalence of chronic disease and risk factors. It is possible that a generally more healthy and health conscious population has a stronger response to population health messages, and consequently the lesser weight gain observed here in consecutive age cohorts over time may be greater than would be observed for the general population. However, the

current observations lend support to the concept that weight gain is decreasing over time in the population, even if the AusDiab cohort represents a particularly sensitive indicator. One further potential limitation is the use of different weighing scales at AusDiab 2 and 3 compared to AusDiab1. Although all scales were calibrated in the same way at each survey wave, differences in variability between the scales may have led to more variability in the change in weight in Period 1 than Period 2.

The results also suggest there is no room for complacency in obesity prevention. The rates of overweight and obesity remain high, the average change in weight and WC remains an increase and there is no reduction in the rate of WC gain. Further, no decrease in the rate of weight or WC change were observed in older men. Finally, the observation that no decrease in rates of weight and WC change is being seen by those living in the most socially disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the social inequalities in obesity, and consequent ill health [24]. It is critical that further studies are conducted to confirm these findings and that we work to identify the causes of the observed changes, including the differences observed in specific population sub-groups.

In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While weight gain may be slowing, it does not appear to be affecting older men or those in more disadvantaged groups, and the same cannot be said for WC.

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Figures

Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

453 **Tables**

454 **Table 1** Comparison of characteristics in 1999/2000 between the included and excluded
455 population

Baseline characteristics	Included	Excluded
n	3351	7896
Sex (% men)	45	45
Age (mean, y)*	49 (11)	52 (16)
Education (% post high school)*	67	56
Area-level disadvantage (% in lowest tertile)	25	36
Born in Australia or New Zealand (%)	80	74
Never smoker (%)*	63	51
Weight (mean, kg)	76 (16)	78 (17)
Waist circumference (mean, cm)	89 (13)	92 (14)
Energy intake (mean, kj/day)	8225 (3112)	8137 (3566)
TV viewing time (mean, minutes/week)	703 (512)	829 (613)
Exercise Time (mean, minutes/week)	283 (329)	269 (332)
Diabetes (%)*	4.9	10.1
Coronary heart disease (%)*	2	5
Hypertension (%)	23	29
High blood cholesterol (%)	26	25

456 Notes: data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 2 Characteristics of the cohort in 1999/2000 and 2005

Cross-sectional characteristics	**2000**	**2005**
Age (mean, y)*	49.3 (11.1)	54.3 (11.1)
Weight (mean, kg)	76.2 (15.6)	77.9 (16.3)
Waist circumference (mean, cm)	89.4 (13.4)	91.6 (13.6)
Smoking status (% never)	63	61
Diabetes (%)	4.9	6.4
Exercise time (mean, minutes/week)*	283 (330)	306 (338)
TV time (mean, minutes/week)*	703 (512)	764 (539)
Energy intake (mean, kj/day)*	8225 (3112)	7681 (2998)
Changes during follow-up	**Period 1**	**Period 2**
Weight change (mean, kg)	1.7 (5.2)	0.9 (6.1)
Waist circumference change (mean, cm)	2.1 (6.2)	3.2 (6.9)
Follow-up (mean, y)*	5.0 (0.15)	6.9 (0.34)
Proportion gaining weight (%)*	64.5	56.8
Annualised weight change (mean, kg/y)*	0.34 (1.04)	0.13 (0.89)
Annualised WC change (mean, cm/y)	0.43 (1.25)	0.46 (1.00)

Notes: Data are % or mean (SD) *Indicates a significant difference ($p<0.05$)

Table 3 Comparison of annualised weight and waist circumference change between Period 1 and Period 2 for matching age groups.

Sex	Age group	Difference in annualised weight change	Difference in annualised waist circumference change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference ($p<0.05$)

Table 4 Difference in annualised change in weight (kg/year) (A) and waist circumference (cm/year) (B) in Period 2 compared to Period 1

(A)

	Sample size	**Annualised weight change in Period 1**	**Difference in annualised change in Period 2 compared to change in Period 1**		
			Model 1	**Model 2**	**Model 3**
Total Population	3351	0.34 (0.30-0.37)	-0.11 (-0.15--0.06)*	-0.10 (-0.15--0.06)*	-0.10 (-0.15--0.06)*
Men	1503	0.29 (0.24-0.34)	-0.08 (-0.14--0.01)*	-0.07 (-0.14--0.01)*	-0.08 (-0.15--0.01)*
Women	1848	0.37 (0.32-0.42)	-0.13 (-0.20--0.07)*	-0.13 (-0.19--0.06)*	-0.13 (-0.19--0.06)*
Age<55	2311	0.46 (0.41-0.50)	-0.12 (-0.19--0.06)*	-0.12 (-0.18--0.06)*	-0.13 (-0.19--0.06)*
Age>=55	1040	0.07 (0.01-0.12)	-0.08 (-0.15--0.02)*	-0.08 (-0.15--0.01)*	-0.07 (-0.14--0.01)*
Education- secondary & trade certificate	2073	0.34 (0.30-0.39)	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*	-0.13 (-0.19--0.07)*
Education- diploma & degree	1278	0.32 (0.27-0.38)	-0.07 (-0.14-0.00)	-0.07 (-0.14-0.00)	-0.06 (-0.14-0.01)
Area level disadvantage- tertile of most disadvantage	1096	0.31 (0.24-0.37)	-0.01 (-0.09-0.07)	-0.01 (-0.09-0.07)	-0.01 (-0.10-0.07)
Area level disadvantage- middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31--0.14)*	-0.22 (-0.31--0.14)*	-0.22 (-0.31--0.14)*
Area level disadvantage- tertile of least	1125	0.30 (0.24-0.35)	-0.08 (-0.16--0.01)*	-0.08 (-0.15--0.00)*	-0.08 (-0.15--0.00)*

disadvantage					
Normal weight	1342	0.4 (0.36-0.44)	-0.07 (-0.13--0.01)*	-0.07 (-0.13--0.01)*	-0.08 (-0.14--0.02)*
Overweight	1375	0.31 (0.26-0.37)	-0.12 (-0.18--0.05)*	-0.11 (-0.18--0.04)*	-0.12 (-0.19--0.05)*
Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*	-0.15 (-0.29--0.01)*
English speaking country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15--0.06)*	-0.1 (-0.15--0.05)*	-0.1 (-0.15--0.05)*
Non-English speaking country of birth	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)	-0.15 (-0.33-0.03)
Never smokers	2121	0.34 (0.29-0.38)	-0.10 (-0.15--0.04)*	-0.1 (-0.15--0.04)*	-0.10 (-0.15--0.04)*
Ex smokers	894	0.27 (0.20-0.34)	-0.15 (-0.24--0.06)*	-0.15 (-0.24--0.06)*	-0.16 (-0.25--0.07)*
Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)	0.00 (-0.20-0.19)
No chronic disease#	1944	0.42 (0.37-0.47)	-0.10 (-0.16--0.04)*	-0.10 (-0.16--0.04)*	-0.09 (-0.15--0.03)*
Chronic disease#	1407	0.25 (0.20-0.30)	-0.12 (-0.19--0.05)*	-0.11 (-0.19--0.04)*	-0.10 (-0.17--0.02)*

(B)

	Sample size	Annualised WC change in Period 1	Difference in annualised change in Period 2 compared to change in Period 1		
			Model 1	**Model 2**	**Model 3**
Total Population	3351	0.43 (0.39-0.48)	0.07 (0.02-0.12)*	0.07 (0.02-0.13)*	0.07 (0.01-0.12)*
Men	1503	0.32 (0.26-0.38)	0.13 (0.05-0.20)*	0.13 (0.06-0.21)*	0.12 (0.05-0.20)*

Women	1848	0.53 (0.47-0.59)	0.02 (-0.06-0.10)	0.03 (-0.05-0.11)	0.02 (-0.05-0.10)
Age<55	2311	0.50 (0.45-0.55)	0.05 (-0.03-0.12)	0.05 (-0.02-0.13)	0.05 (-0.03-0.12)
Age>=55	1040	0.28 (0.21-0.35)	0.10 (0.02-0.18)*	0.10 (0.02-0.19)*	0.10 (0.02-0.18)*
Education- secondary & trade certificate	2073	0.44 (0.39-0.49)	0.09 (0.02-0.15)*	0.09 (0.02-0.16)*	0.08 (0.01-0.15)*
Education- diploma & degree	1278	0.43 (0.36-0.50)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)	0.05 (-0.04-0.14)
Area level disadvantage- tertile of most disadvantage	1096	0.41 (0.34-0.49)	0.13 (0.04-0.23)*	0.13 (0.04-0.23)*	0.14 (0.04-0.23)*
Area level disadvantage- middle tertile	1130	0.32 (0.24-0.40)	0.21 (0.11-0.31)*	0.22 (0.12-0.32)*	0.22 (0.12-0.32)*
Area level disadvantage- tertile of least disadvantage	1125	0.57 (0.50-0.64)	-0.14 (-0.23--0.05)*	-0.13 (-0.22--0.05)*	-0.15 (-0.23--0.06)*
Normal weight	1342	0.48 (0.42-0.54)	0.04 (-0.04-0.12)	0.04 (-0.04-0.12)	0.03 (-0.05-0.12)
Overweight	1375	0.43 (0.36-0.49)	0.08 (-0.01-0.16)	0.08 (-0.00-0.17)	0.07 (-0.02-0.15)
Obese	633	0.35 (0.24-0.46)	0.12 (-0.01-0.26)	0.13 (-0.00-0.27)	0.11 (-0.02-0.25)
English speaking country of birth	3129	0.44 (0.40-0.48)	0.06 (0.01-0.12)*	0.07 (0.01-0.13)*	0.06 (0.01-0.12)*
Non-English speaking country of birth	222	0.35 (0.18-0.52)	0.17 (-0.04-0.38)	0.18 (-0.02-0.39)	0.17 (-0.03-0.38)
Never smokers	2121	0.44 (0.39-0.49)	0.07 (0.00-0.14)*	0.07 (0.01-0.14)*	0.07 (0.00-0.14)*

Ex smokers	894	0.38 (0.30-0.46)	0.04 (-0.06-0.14)	0.04 (-0.06-0.14)	0.03 (-0.08-0.13)
Current smokers	336	0.56 (0.40-0.71)	0.17 (-0.05-0.39)	0.17 (-0.05-0.40)	0.18 (-0.04-0.41)
Chronic disease[1]	1944	0.47 (0.41-0.52)	0.06 (-0.01-0.13)	0.07 (-0.01-0.14)	0.07 (-0.01-0.14)
No chronic disease[1]	1407	0.44 (0.39-0.49)	0.08 (-0.00-0.17)	0.09 (0.00-0.17)*	0.1 (0.01-0.18)*

Model 1- adjusting for age and sex

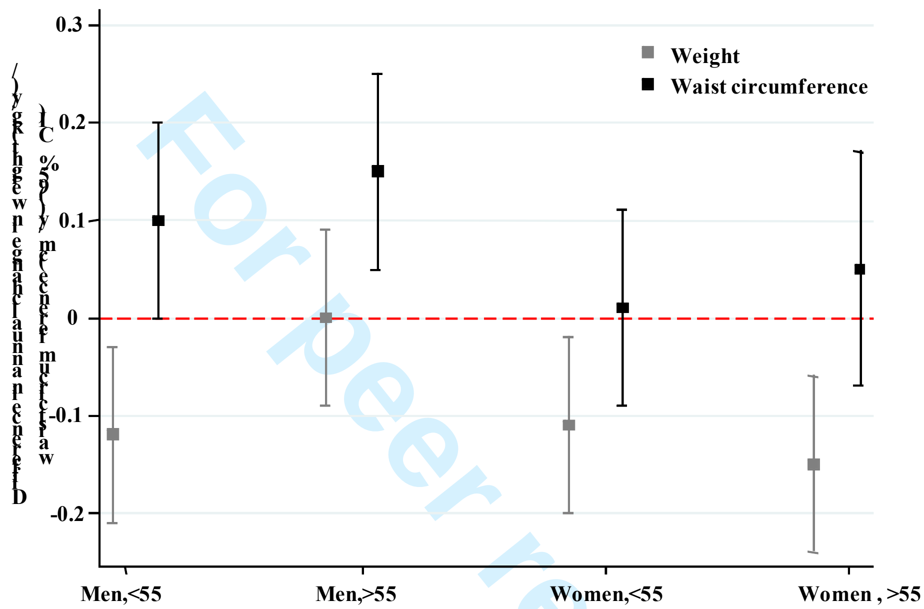
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

Model 3- additionally adjusting for baseline BMI and diabetes status

* indicates $p<0.05$

1 Chronic disease refers to any of coronary heart disease, cholesterol, hypertension, or diabetes at baseline

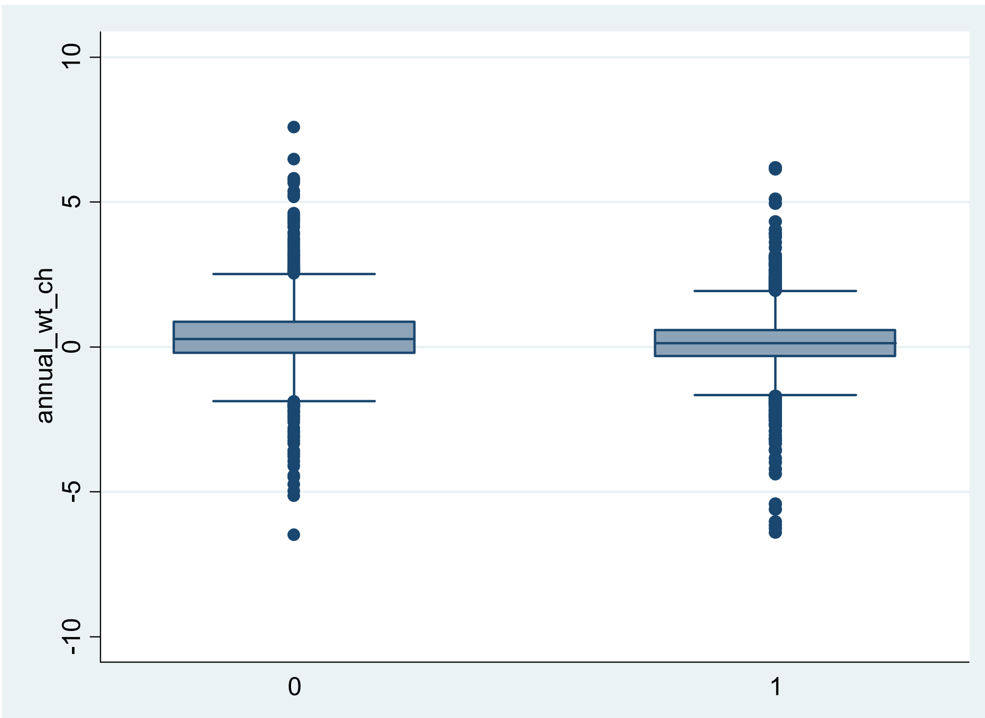
Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.



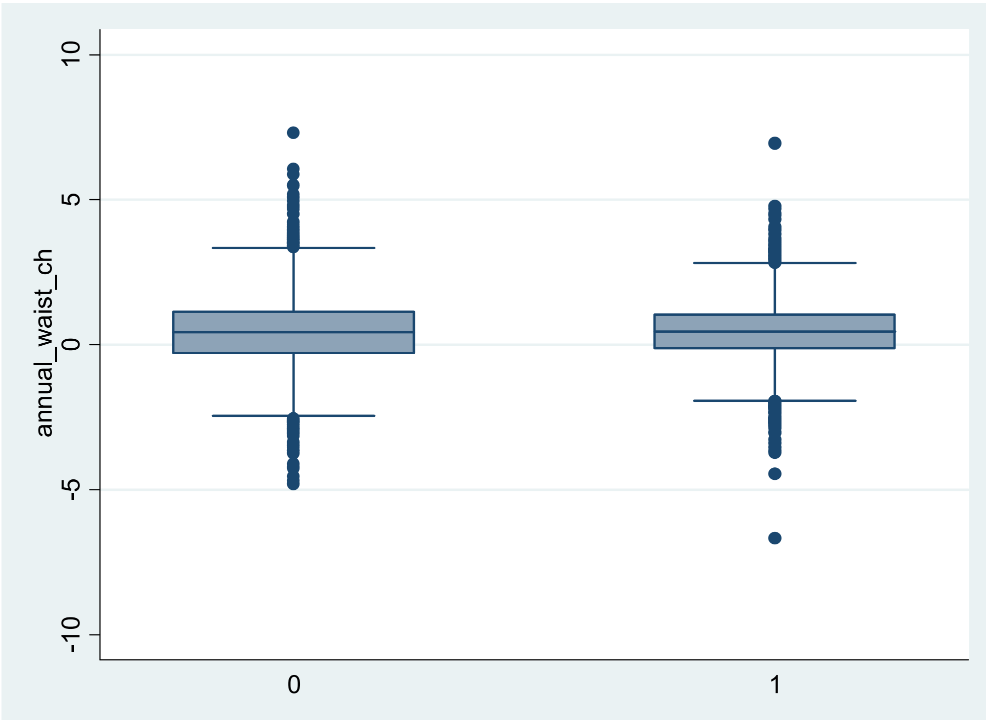
Appendix

Figure 1 Annualised weight and waist circumference change in Period 1 and Period 2

A. Annualised weight change



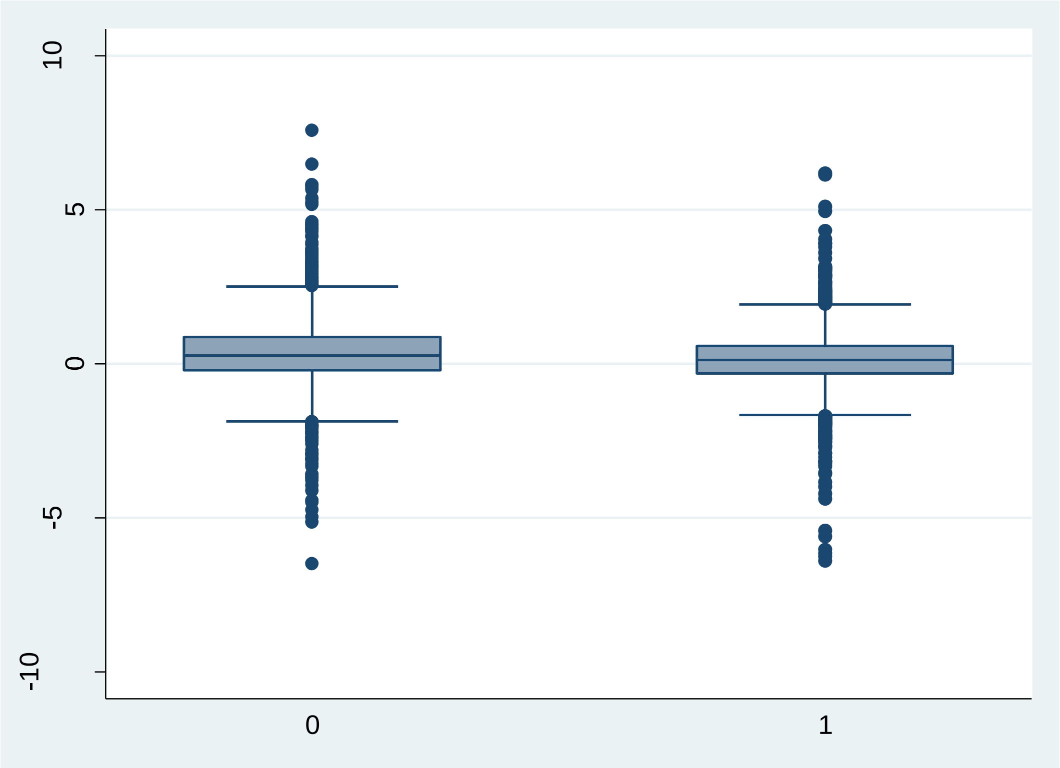
B. Annualised waist circumference change



Appendix

Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



B. Annual waist circumference change

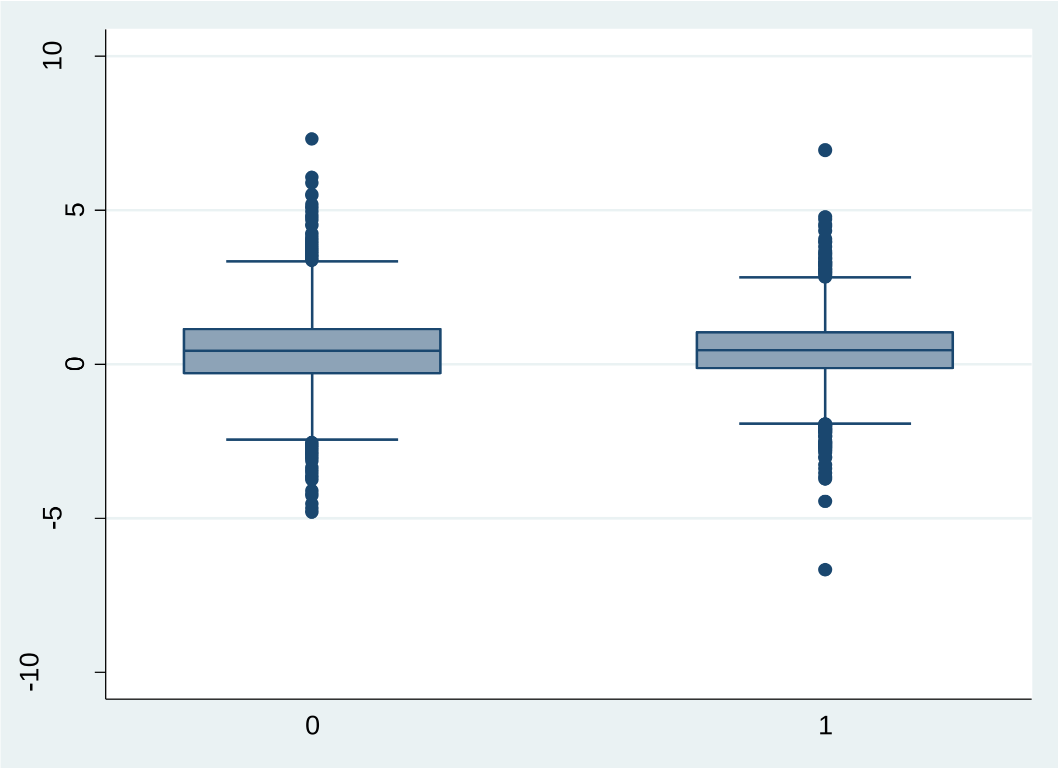


Table 1 Comparison of annual weight and waist circumference change between Period 1 and Period 2 for matching age groups.

Sex	Age group	Difference in annual weight change	Difference in annual WC change
Men			
	25-34	-0.08 (-0.5.0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34,-0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
Women			
	25-34	-0.08 (-0.46, 0.31)	-0.05 (-0.47, 0.37)
	35-44	-0.12 (-0.26, 0.03)	-0.02 (-0.19, 0.16)
	45-54	-0.15 (-0.26, -0.04)*	-0.01 (-0.14, 0.12)
	55-64	-0.09 (-0.20, 0.02)	0.08 (-0.07, 0.23)
	65-74	-0.34 (-0.50, -0.17)*	-0.08 (-0.31, 0.16)
	75+	0.02 (-0.37, 0.41)	0.27 (-0.32, .85)

*Indicates a significant difference (p<0.05)

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract YES
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found YES
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported YES
Objectives	3	State specific objectives, including any prespecified hypotheses YES
Methods		
Study design	4	Present key elements of study design early in the paper YES
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection YES
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up YES,
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed N/A
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable YES
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). YES Describe comparability of assessment methods if there is more than one group N/A
Bias	9	Describe any efforts to address potential sources of bias YES
Study size	10	Explain how the study size was arrived at YES
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why YES
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding YES
		(*b*) Describe any methods used to examine subgroups and interactions YES
		(*c*) Explain how missing data were addressed YES
		(*d*) If applicable, explain how loss to follow-up was addressed YES
		(*e*) Describe any sensitivity analyses YES

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed YES
		(b) Give reasons for non-participation at each stage NOT DONE
		(c) Consider use of a flow diagram NOT DONE
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders YES
		(b) Indicate number of participants with missing data for each variable of interest DONE IN AGGREGATE
		(c) Summarise follow-up time (eg, average and total amount) YES
Outcome data	15*	Report numbers of outcome events or summary measures over time YES
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included YES
		(*b*) Report category boundaries when continuous variables were categorized N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses YES
Discussion		
Key results	18	Summarise key results with reference to study objectives YES
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias YES
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence YES
Generalisability	21	Discuss the generalisability (external validity) of the study results YES
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based YES

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.