



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

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3 20 *Data sharing*
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6 21 Extra data is available by emailing A Peeters at anna.peeters@bakeridi.edu.au
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12 23 *Authorship statement*
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15 24 AP conceived of the article, executed the analysis and writing of the article and is guarantor
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17 25 for the article. JS, DM and KB contributed to the ideas included within and writing of the
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19 26 article, and provision of data. PZ contributed to the writing of the article and provision of
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21 27 data.
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3 49 *Article summary*
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6 50 *Article focus*
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- 9 • We aimed to assess for the first time in a single cohort whether annual change in
10 weight and waist circumference has changed in recent time periods.
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14 53 *Key messages*
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- 17 • Between 2004/5–2011/2, Australian adults in this national cohort study continued to
18 gain weight, but more slowly than 1999/2000–2004/5.
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- 21 • In contrast waist circumference gain was greater in the most recent period. Important
22 differences were observed according to area-level disadvantage.
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- 25 • While some obesity prevention strategies may be working, they do not appear to be
26 affecting those in more disadvantaged areas.
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32 60 *Strengths and limitations*
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- 35 • Reliably measured data in a single nationally representative cohort in recent time
36 periods
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- 39 • Selection and response bias may limit the generalisability of the results to the broader
40 Australian population
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66 **ABSTRACT**

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

69 Design: Longitudinal cohort study with three surveys, 1 – 1999/2000; 2 – 2004/2005; 3 –
70 2011/2012. Generalized linear mixed models with random effects were used to compare
71 annual weight and WC change between surveys 1 and 2 (Period 1) with that between surveys
72 2 and 3 (Period 2). Models were adjusted for age, sex, education status, area-level
73 disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

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

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

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

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

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

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3 88 may be working, they do not appear to be affecting WC, older men or those in more

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5 89 disadvantaged groups.

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3 91 Obesity in adults has increased rapidly over the past few decades, leading to prevalence of
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5 92 over one quarter in many developed countries. There is growing acceptance that strong
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7 93 preventive measures are required to stem the increasing prevalence, with a variety of
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10 94 approaches implemented, ranging from social marketing through whole of community
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12 95 interventions to regulatory strategies. However, it is difficult to evaluate whether elements of
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14 96 the approach to date have had a beneficial effect.

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17 97 There have been some suggestions that obesity prevention interventions in children have had
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19 98 a positive effect, due to the observation that the prevalence of obesity is no longer increasing
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21 99 at the same rate. A recent review of 52 studies, from 25 countries, comparing obesity
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24 100 prevalence at two time points since 1999 [1] concluded that in more developed nations a
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26 101 likely slowing of the rate of increase in obesity prevalence was occurring in children, with a
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28 102 possible turning point around 2000. However, trends in adults generally appeared to be
29
30 103 continuing to increase. Since this review, an analysis of US adults through the repeated
31
32 104 National Health and Nutrition Examination Surveys (NHANES) between 1999 and 2010
33
34 105 suggested no increase in mean body mass index (BMI) or obesity prevalence over that time
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36 106 period in non-Hispanic white and Hispanic women, but continued increases in men and non-
37
38 107 Hispanic black and Mexican American women [2]. In Australia, the latest reported data
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40 108 suggests a continued increase in obesity prevalence in adults to 2012 [3]. However,
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42 109 prevalence data is driven by a range of factors, including migration, mortality and response
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44 110 bias. To determine whether the degree of weight gain in the population has slowed over time,
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46 111 a comparison of the rates of weight change is required.

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51 112 We aimed to analyse whether the degree of change in weight and waist circumference (WC)
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53 113 over time differed in a single cohort of adults, comparing weight and WC change in the same
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55 114 individuals between two consecutive time periods. We used the national Australian Diabetes,
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3 115 Obesity and Lifestyle cohort (AusDiab) [4], and compared annual change in weight and WC
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5 116 between 2000 and 2005 to that between 2005 and 2012.
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3 118 **METHODS**
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6 119 **Setting and Participants**
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9 120 The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based,
10
11 121 stratified-cluster survey of 11, 247 adults aged ≥ 25 years, recruited in 1999 -2000
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13 122 (AusDiab1). Methods and response rates have been described previously[4]. Five-year
14
15 123 follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted
16
17 124 in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical
18
19 125 examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3,
20
21 126 respectively. For this analysis we excluded participants with missing data on weight or WC
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23 127 at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those
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25 128 participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a
26
27 129 final sample size of 3,351. Ethics approval was obtained from the International Diabetes
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29 130 Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented
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31 131 to participate in the study.
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36 132 All study assessments followed a similar protocol. Data were collected by interviewer-
37
38 133 administered questionnaires on medical history, lifestyle and health behaviour. Data on
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40 134 education, country of birth, smoking and physical activity and television viewing habits
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42 135 were obtained by questionnaire. Self-reported cardiovascular disease was ascertained by
43
44 136 asking if participants had been told by a doctor or nurse that they had angina, myocardial
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46 137 infarction, or stroke.
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50 138 Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than
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52 139 daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked
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54 140 tobacco daily) combined.
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3 141 Education level was ascertained by asking the question “Which of these describes the highest
4
5 142 qualification you have received?” Education was categorised as secondary only (comprising
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7 143 those with a secondary school qualification), diploma (comprising nursing or teaching
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9 144 qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor
10
11 145 degree, post-graduate diploma or masters degree/doctorate)[5].
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15 146 Area-level disadvantage was estimated using the Index of Relative Disadvantage code from
16
17 147 the Socio-economic Indexes for Areas (SEIFA). The index was developed by the Australian
18
19 148 Bureau of Statistics, to create a summary measure from a group of 20 variables (related to
20
21 149 education, income, employment, family composition, housing benefits, car ownership,
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23 150 ethnicity, English language proficiency, residential overcrowding) displaying dimensions of
24
25 151 social disadvantage [6]. The index is constructed so that high values reflect areas with high
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27 152 socio-economic status (relative advantage) and low values reflect areas with low socio-
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29 153 economic status (relative disadvantage). Tertiles of disadvantage were calculated amongst the
30
31 154 final study sample.
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36 155 Physical activity was measured via an interviewer-administered Active Australia
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38 156 questionnaire, which considered participation in predominantly leisure-time physical
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40 157 activities (including walking for transport) during the previous week [7]. Total physical
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42 158 activity time was calculated as the sum of the time spent walking (if continuous and for ≥ 10
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44 159 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-
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46 160 intensity physical activity [8].
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50 161 Self-reported television viewing time was calculated as the total time spent watching
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52 162 television or videos in the previous week, and is considered a reliable and valid estimate of
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54 163 television viewing time among adults [9].
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3 164 Average daily energy intake was assessed using a self-administered validated food frequency
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5 165 questionnaire (FFQ) [10], which included 74 items (with 10 frequency options), with
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7 166 additional questions on food habits, portion size and consumption of alcoholic beverages. In
8
9 167 AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the
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11 168 state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential
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13 169 measurement error, manual blood pressure measurements were adjusted as previously
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15 170 described [Briganti, Shaw et al. 2003]. In AusDiab 2 and 3, blood pressure was measured by
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17 171 an Omron machine. Fasting serum total cholesterol was measured with an Olympus AU600
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19 172 analyser (Olympus Optical, Tokyo, Japan) at a central laboratory [11].
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23 173 Classification of diabetes status has been described elsewhere [11]. Briefly, participants were
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25 174 classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and
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27 175 were either taking hypoglycaemic medication or had fasting plasma glucose (FPG)
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29 176 ≥ 7.0 mmol/L or a 2-hour plasma glucose (PG) ≥ 11.1 mmol/L. Participants not reporting
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31 177 diabetes but with FPG ≥ 7.0 mmol/L or 2-hour PG ≥ 11.1 mmol/L were classified as having
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33 178 'newly diagnosed diabetes'.
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36 179 **Outcomes**

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39 180 Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm.
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41 181 Weight was measured without shoes, excess clothing, and items in pockets by a single
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43 182 measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam
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45 183 balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was
46
47 184 recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior
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49 185 to each set of measurements. BMI was obtained from the calculation of weight (kg) divided
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51 186 by height (m²). Annual weight change was calculated as the difference in weight between
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53 187 AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time
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55 188 between the two consecutive surveys.
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3 189 Waist circumference was measured twice, halfway between the lower border of the ribs and
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5 190 the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the
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7 191 mean of the two closest measurements was calculated. Annual WC change was calculated as
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10 192 the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by the follow-
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12 193 up time between the two consecutive surveys.

14 194 **Statistical analysis**

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17 195 Baseline characteristics (means and proportions at AusDiab1) were compared between
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19 196 AusDiab participants with and without complete measures at AusDiab 1, 2 and 3.
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21 197 Characteristics of the included population were also compared in 2000 and 2005,
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23 198 representing the two baseline surveys for the two weight change periods.

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26 199 The difference in annual weight and WC change in Period 1 (2000 to 2005), compared to
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28 200 Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear
29
30 201 mixed models with random effects were used to analyse the association between study period
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32 202 on annual weight or WC change. This model includes random effects associated with both
33
34 203 the cluster and the units of analysis (participants) to take the clustered structure of the data
35
36 204 into account and to allow the residuals associated with the longitudinal measures on the same
37
38 205 unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model
39
40 206 1), additionally adjusting for smoking, education, area level disadvantage and country of birth
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42 207 (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and
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44 208 additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4).
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47 209 Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2
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49 210 for change in Period 2. The association between study period and annual weight and WC
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51 211 change was also analysed across sub-groups and interaction terms between study period with
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53 212 age or sex were analysed.
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3 213 The primary analyses were repeated after excluding the few participants with annual weight
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5 214 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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7 215 age group of 30–80.
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10 216 All analyses were performed in STATA (version 11.0), with statistical significance set at the
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12 217 5% level.
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3 219 **RESULTS**
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6 220 The population with complete measures was similar to the total AusDiab cohort with respect
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8 221 to sex and weight, but was younger, with higher educational attainment, and a higher
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10 222 prevalence of never smoking (Table 1). The population with complete measures also had a
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12 223 lower prevalence of chronic disease. There was no appreciable difference between the two
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14 224 groups for weight change in Period 1 after adjustment for differences in age and sex.

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18 225 (Table 1 here)
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21 226 Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to
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23 227 being five years older, the population had a higher prevalence of diabetes (predominantly
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25 228 type 2). In both periods the average change in weight and WC was a gain. In Period 2, a
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27 229 smaller proportion of the population gained weight and annual weight gain was less, at 0.13
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29 230 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser weight
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31 231 change across the entire distribution of weight change in Period 2, with minimal difference at
32
33 232 the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile of weight
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35 233 change (Appendix Figure 1A). For WC, there was no difference in the crude annual change
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37 234 between the two periods (Table 2). In contrast to weight change, this resulted from both a
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39 235 smaller gain in those whose WC increased and a smaller loss in those whose WC decreased
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41 236 (Appendix Figure 1B). The correlation between annual weight change and annual WC
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43 237 change was 0.69 (0.68 in Period 1, and 0.71 in Period 2).
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48 238 (Table 2 here)
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51 239 Comparison of the crude annual weight change for matching 10-year age-groups in Periods 1
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53 240 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups, although these
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55 241 differences were only significant for men aged 35–44, and women 45–54 and 65–74
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3 242 (Appendix Table 1). Comparison of the crude annual WC change for matching age-groups in
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5 243 Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a
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7 244 generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64;
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9 245 Appendix Table 1).

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12 246 The difference in annual weight and WC change in Period 2, compared to Period 1, was
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14 247 assessed using linear regression analysis (Table 3A). In Period 2, annual weight gain was
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16 248 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after
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18 249 further adjustment for smoking status, education status, ethnicity, area-level disadvantage,
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20 250 baseline BMI and diabetes status (Table 3A), nor after adjustment for TV time, exercise time
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22 251 and energy intake (results not shown).

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27 252 Annual weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 3A),
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29 253 with suggestions of a greater difference over time in women, and those aged under 55 years
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31 254 (although no interaction tests on these factors were significant). Annual weight gain in Period
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33 255 2 was non-significantly less than in Period 1 for those with high educational attainment
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35 256 (borderline significant), obesity, and those from a non-English speaking background. No
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37 257 difference in annual weight gain between the two periods was observed for those in the tertile
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39 258 of greatest area-level disadvantage, nor for current smokers.

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43 259 In Period 2, annual WC gain was 0.07 cm/year more than in Period 1 (Table 3B). This did not
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45 260 alter substantially after further adjustment for smoking status, education status, area-level
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47 261 disadvantage, ethnicity, baseline BMI and diabetes status (Table 3B), nor after adjustment for
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49 262 TV time, exercise time and energy intake (results not shown).

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53 263 In stratified analyses no difference in annual WC gain between the two periods was observed
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55 264 for women, those aged <55 years, those in the highest education group, those with normal
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3 265 weight nor ex-smokers. Annual WC gain was less in Period 2 than Period 1 for those in the
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5 266 tertile of least area-level disadvantage (-0.14cm/year 95%CI -.05, -0.23).
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8 267 (Table 3 here)
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11 268 For both weight and WC, there was an apparent combined sex and age effect, such that older
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13 269 men had the least favourable changes over time (Figure 1).
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16 270 The primary analyses were repeated after excluding the few participants with annual weight
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18 271 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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20 272 age group of 30–80. No differences in results were seen.
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29 275 **DISCUSSION**

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33 276 In this analysis of a single cohort of Australian adults, weight and WC increased in the most
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35 277 recent period in all population sub-groups examined. Annual weight gain between 2005–2012
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37 278 was less than between 1999/2000–2005, but annual WC gain was greater. Improvements over
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39 279 time were not seen in older men or those with greatest area-level social disadvantage.
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46 281 The lack of difference in annual weight and WC change between the two periods observed
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48 282 for current smokers, those from a non-English speaking background and those with obesity,
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50 283 is likely to reflect small sample sizes in these groups. In general, adjustment for covariates
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52 284 had little effect on the observed associations between study period and annual weight and
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54 285 WC change. As time spent watching TV, exercise and energy intake might be expected to be
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56 286 mediating some of the observed changes, we had expected a greater impact after adjustment
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3 287 for these factors. The lack of impact after adjustment likely reflects that they are relatively
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5 288 blunt instruments to detect small changes in behaviour over time.
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8 289 The general observation that annual weight gain may be lessening over time supports the
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10 290 cross-sectional time series observations of a plateau in the prevalence of obesity and rate of
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12 291 change in BMI. However, these results also suggest that the general observations do not tell
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14 292 the whole story, with large differences between different population subgroups, and a
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16 293 contrasting observation for waist circumference. The sex differences observed here are
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18 294 similar to the cross-sectional trends reported for American adults for whom a clear plateau in
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20 295 obesity prevalence has been observed for women but not men [2]. The differences we
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22 296 observed according to level of area-level disadvantage also reflect findings from the review
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24 297 of obesity trends in which the levelling off of obesity was generally more pronounced in
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26 298 groups with higher socio-economic position [1]. It is possible, based on current reports of
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28 299 levelling off of obesity prevalence in children, that different trends would be observed in
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30 300 Australian children, and it will be important to do a similar analysis in a longitudinal
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32 301 children's cohort.
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37 302 The observation that rates of WC change may be continuing to increase even as rates of
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39 303 weight change decrease may reflect prior findings using the NHANES data that WC is
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41 304 increasing to a greater extent than expected from changes in weight [12] [13]. While we
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43 305 observed changes in weight and WC to be highly correlated these results combined suggest a
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45 306 preferential increase in abdominal adiposity over time, which is thought to be associated with
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47 307 greater risk of cardio-metabolic outcomes [14]. The potential implication that current
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49 308 bodyweight trends are leading a more metabolically active obesity, with increased risks for
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51 309 outcomes such as diabetes, hypertension and cardiovascular disease warrants further
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53 310 investigation.
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3 311 The key strength of the current study is that for the first time it addresses this important
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5 312 question through an analysis of the same cohort of adults over two distinct but recent time
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7 313 periods. In doing this, conclusions can be drawn about the changes over time independent of
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9 314 unmeasurable differences in cohorts. Other strengths include the national population
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11 315 sampling strategy of the AusDiab cohort and the measured weight and WC at each study
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13 316 wave.

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17 317 The potential limitation of the current study is the lack of generalisability of the included
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19 318 cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who
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21 319 attended all three waves are more select again, with higher educational attainment and a
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23 320 lower prevalence of chronic disease and risk factors. It is possible that a generally more
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25 321 healthy and health conscious population has a stronger response to population health
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27 322 messages, and consequently the decrease in weight gain observed here over time may be
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29 323 greater than would be observed for the general population. However, the current observations
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31 324 lend support to the concept that weight gain is decreasing over time in the population, even if
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33 325 the AusDiab cohort represents a particularly sensitive indicator.

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37 326 The results also suggest there is no room for complacency in obesity prevention. The rates of
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39 327 overweight and obesity remain high, the average change in weight and WC remains an
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41 328 increase and there is no reduction in annual WC gain. Further, no improvements in weight or
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43 329 WC change were observed in older men. Finally, the observation that no improvements in
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45 330 rates of weight and WC change are being seen by those living in the most socially
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47 331 disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the
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49 332 social inequalities in obesity, and consequent ill health [15]. It is critical that further studies
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51 333 are conducted to confirm these findings and that we work to identify the causes of the
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53 334 observed improvements, as well as the lack of improvement in WC and specific population
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55 335 sub-groups.
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3 336 In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a
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5 337 faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While some
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7 338 obesity prevention strategies may be working, they are not affecting WC, older men or those
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9 339 in lower SEP groups.
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348 **References**

- 349 1. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the
350 year 1999--a review of evidence and perspectives. *Obes Rev* 2010;**11**(12):835-46 doi:
351 10.1111/j.1467-789X.2010.00810.x[published Online First: Epub Date]].
- 352 2. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the
353 distribution of body mass index among US adults, 1999-2010. *JAMA*
354 2012;**307**(5):491-7 doi: 10.1001/jama.2012.39[published Online First: Epub Date]].
- 355 3. Statistics ABo. Australian Health Survey: First Results, 2011-12. Canberra: Australian
356 Bureau of Statistics, 2012.
- 357 4. Dunstan DW, Zimmet PZ, Welborn TA, et al. The Australian Diabetes, Obesity and
358 Lifestyle Study (AusDiab)--methods and response rates. *Diabetes Res Clin Pract*
359 2002;**57**(2):119-29
- 360 5. Williams ED, Magliano DJ, Zimmet PZ, et al. Area-level socioeconomic status and
361 incidence of abnormal glucose metabolism: the Australian Diabetes, Obesity and
362 Lifestyle (AusDiab) study. *Diabetes Care* 2012;**35**(7):1455-61 doi: 10.2337/dc11-
363 1410[published Online First: Epub Date]].
- 364 6. Statistics ABo. Information Paper - Census of Population and Housing: Socio-Economic
365 Indexes for Areas Australia 2001. : Australian Bureau of Statistics, 2001.
- 366 7. Australian Institute of Health and Welfare. The Active Australia Survey. A guide and
367 manual for implementation, analysis and reporting. Canberra: Australian Institute of
368 Health and Welfare, 2003.
- 369 8. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results
370 of the 1999 National Physical Scivity Survey. Australian Institute of Health and
371 Welfare cat No CVD10. Canberra: Australian Institute of Health and Welfare, 2000.

- 1
2
3 372 9. Salmon J, Bauman A, Crawford D, Timperio A, Owen N. The association between
4
5 373 television viewing and overweight among Australian adults participating in varying
6
7 374 levels of leisure-time physical activity. *Int. J. Obes. Relat. Metab. Disord.*
8
9 375 2000;**24**:600-6
- 10
11 376 10. Ireland P, Jolley D, Giles G, et al. Development of the Melbourne FFQ: A food frequency
12
13 377 questionnaire for use in an Australian prospective study involving an ethnically
14
15 378 diverse cohort. *Asia Pacific J Clin Nutr* 1994;**3**:19-31
- 16
17
18 379 11. Magliano DJ, Barr EL, Zimmet PZ, et al. Glucose indices, health behaviors, and
19
20 380 incidence of diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle
21
22 381 Study. *Diabetes Care* 2008;**31**(2):267-72 doi: 10.2337/dc07-0912[published Online
23
24 382 First: Epub Date]].
- 25
26
27 383 12. Elobeid MA, Desmond RA, Thomas O, Keith SW, Allison DB. Waist circumference
28
29 384 values are increasing beyond those expected from BMI increases. *Obesity (Silver*
30
31 385 *Spring)* 2007;**15**(10):2380-3 doi: 15/10/2380 [pii]
32
33 386 10.1038/oby.2007.282[published Online First: Epub Date]].
- 34
35
36 387 13. Walls HL, Stevenson CE, Mannan HR, et al. Comparing trends in BMI and waist
37
38 388 circumference. *Obesity (Silver Spring)* 2011;**19**(1):216-9 doi: oby2010149 [pii]
39
40 389 10.1038/oby.2010.149[published Online First: Epub Date]].
- 41
42
43 390 14. Welborn TA, Dhaliwal SS, Bennett SA. Waist-hip ratio is the dominant risk factor
44
45 391 predicting cardiovascular death in Australia. *Med J Aust* 2003;**179**(11-12):580-5
- 46
47 392 15. Backholer K, Mannan HR, Magliano D, et al. Projected socioeconomic disparities in the
48
49 393 prevalence of obesity amongst Australian adults. *Australian and New Zealand Journal*
50
51 394 *of Public Health* 2012;**in press**
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398 **Figures**

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

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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, 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
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)

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5	disadvantage				
6	Area level disadvantage-				
7	middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31-- 0.14)*	-0.22 (-0.31--0.14)*
8					
9	Area level disadvantage-				
10	tertile of least	1125	0.30 (0.24-0.35)	-0.08 (-0.16-- 0.01)*	-0.08 (-0.15--0.00)*
11	disadvantage				
12	Normal weight				
13		1342	0.4 (0.36-0.44)	-0.07 (-0.13-- 0.01)*	-0.07 (-0.13--0.01)*
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15	Overweight				
16		1375	0.31 (0.26-0.37)	-0.12 (-0.18-- 0.05)*	-0.11 (-0.18--0.04)*
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18	Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*
19					
20	English speaking				
21	country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15-- 0.06)*	-0.1 (-0.15--0.05)*
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23	Non-English speaking	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)
24	country of birth				
25	Never smokers				
26		2121	0.34 (0.29-0.38)	-0.10 (-0.15-- 0.04)*	-0.1 (-0.15--0.04)*
27					
28	Ex smokers				
29		894	0.27 (0.20-0.34)	-0.15 (-0.24-- 0.06)*	-0.15 (-0.24--0.06)*
30					
31	Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)
32					
33	No chronic disease#				
34		1944	0.42 (0.37-0.47)	-0.10 (-0.16-- 0.04)*	-0.10 (-0.16--0.04)*
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	Sample size	Annual WC change in Period 1	Model 1	Model 2	Model 3
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)*
<i>(B)</i>					
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)*

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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

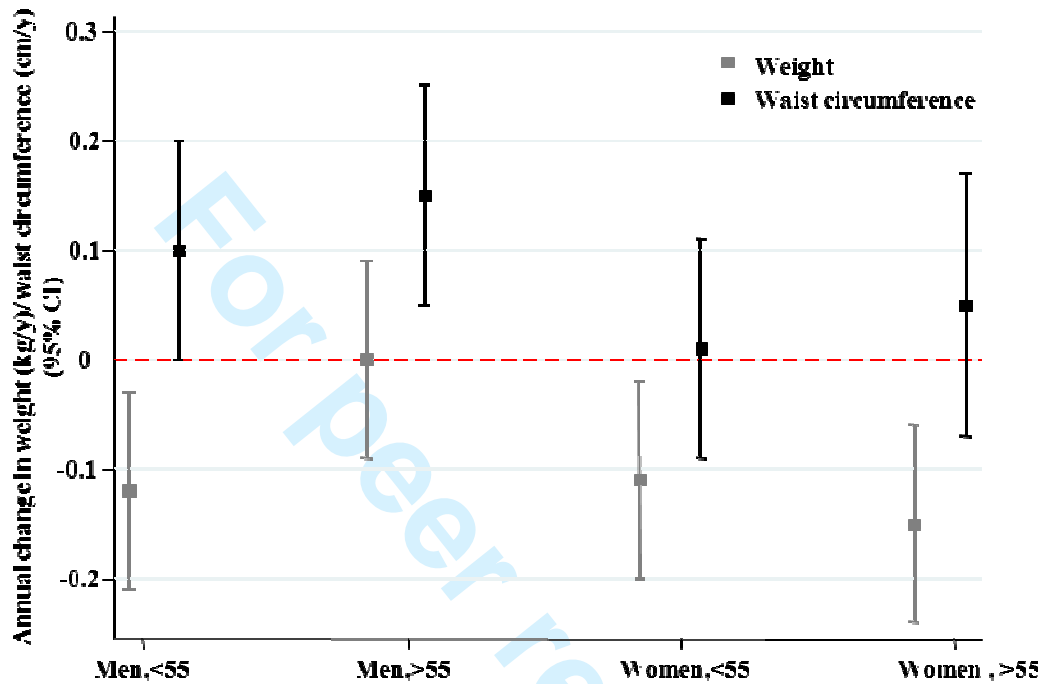
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

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.

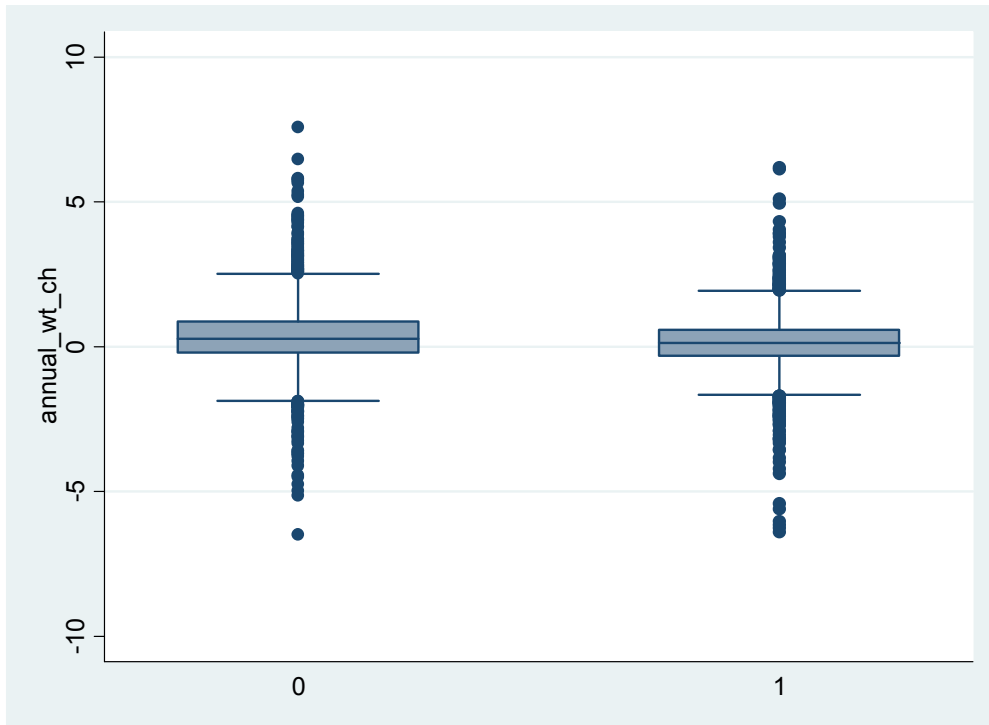


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Appendix

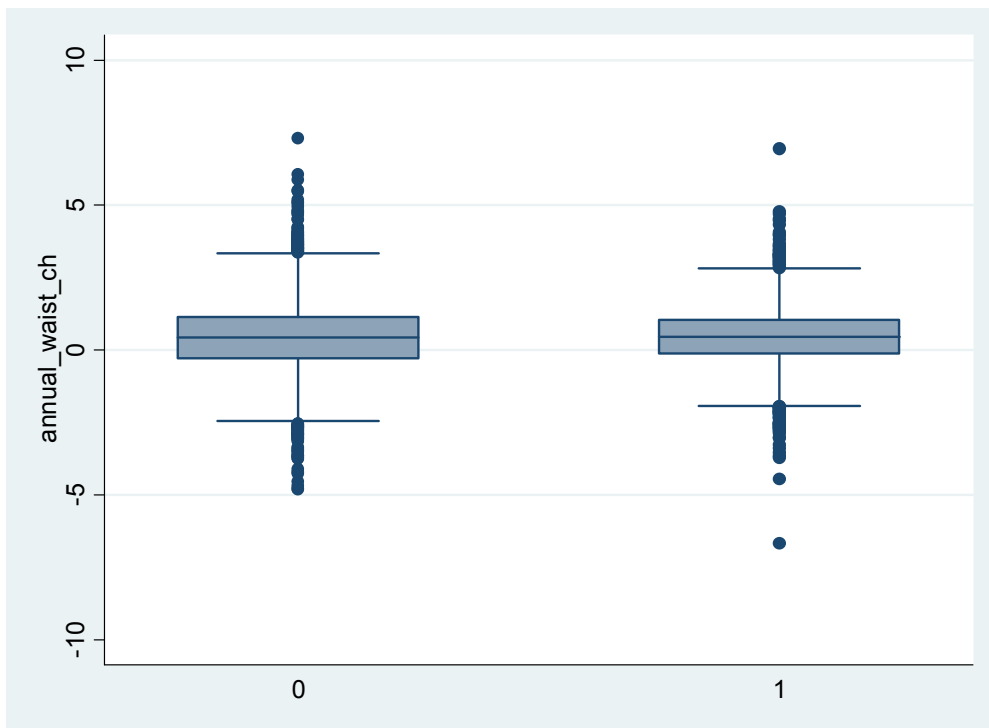
Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



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B. Annual waist circumference change



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

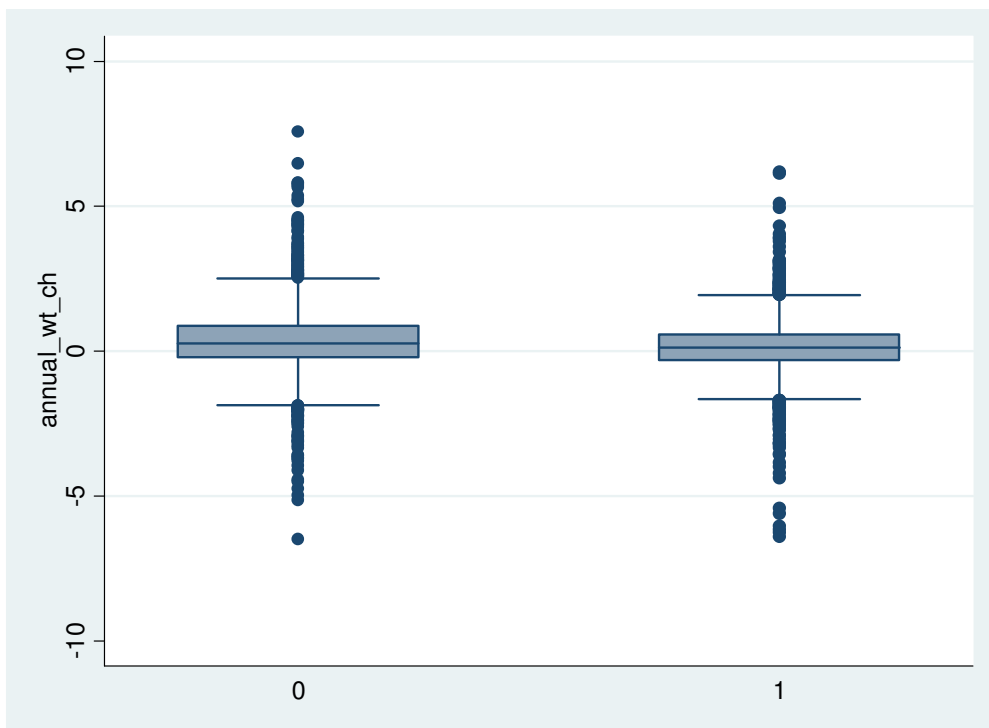
Sex	Age group	Difference in annual weight change	Difference in annual WC change
Men	25-34	-0.08 (-0.5, 0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34, -0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	0.05 (-0.12, 0.23)
	75+	0.27 (-0.10, 0.65)	0.26 (-0.19, 0.72)
	Women	25-34	-0.08 (-0.46, 0.31)
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



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B. Annual waist circumference change

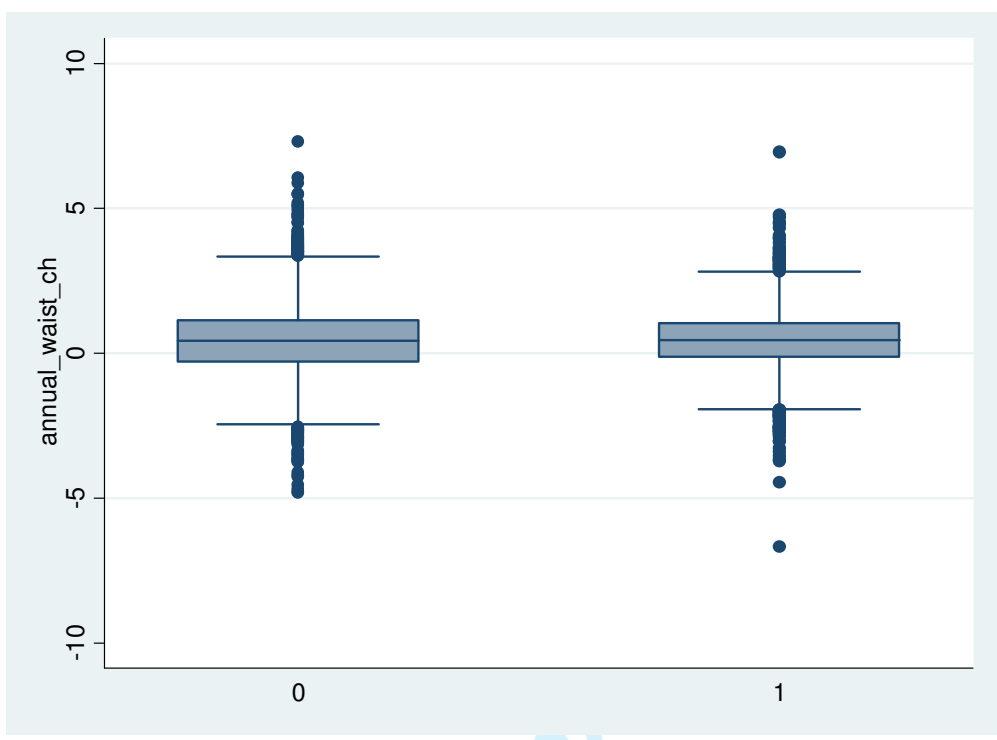


Table 1 Comparison of annual weight and waist circumference change between Period 1 and Period 2 for matching age groups.

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)
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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Manuscripts

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3 1 **Changes in the rates of weight and waist circumference gain in Australian adults over**
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5 2 **time.**
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9 **Running title:** Change in weight and waist gain over time

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3 21 **ABSTRACT**
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6 22 **Objective:** To assess in a single cohort whether annual weight and waist circumference (WC)
7
8 23 change has varied over time.
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11 24 **Design:** Longitudinal cohort study with three surveys, 1 – 1999/2000; 2 – 2004/2005; 3 –
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13 25 2011/2012. Generalized linear mixed models with random effects were used to compare
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15 26 annualised weight and WC change between surveys 1 and 2 (Period 1) with that between
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17 27 surveys 2 and 3 (Period 2). Models were adjusted for age to analyse changes with time rather
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19 28 than age. Models were additionally adjusted for sex, education status, area-level socio-
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21 29 economic disadvantage, ethnicity, body mass index, diabetes status, and smoking status.
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25 30 **Setting:** The Australian Diabetes, Obesity and Lifestyle study (AusDiab) - a population-
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27 31 based, stratified-cluster survey of 11, 247 adults aged ≥ 25 years.
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31 32 **Participants:** 3,351 Australian adults who attended each of three surveys and had complete
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33 33 measures of weight, WC and covariates.
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37 34 **Primary outcome measures:** Weight and WC were measured according to standard
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39 35 protocols at each survey. Change in weight and WC was annualised for comparison between
40
41 36 the two Periods.
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44 37 **Results:** Mean weight and WC increased in both Periods. Annualised weight gain in Period
45
46 38 2 was 0.11kg/year (95% CI 0.06–0.15) less than in Period 1. Lesser annual weight gain
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48 39 between the two periods was not seen for those with greatest area-level socio-economic
49
50 40 disadvantage, or in men over the age of 55. In contrast, the annualised WC increase in Period
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52 41 2 was greater than in Period 1 (0.07cm/year, 95% CI 0.01–0.12). The increase was greatest in
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54 42 males 55+ and those with greater area-level socio-economic disadvantage.
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3 43 **Conclusions:** Between 2004/5–2011/2, Australian adults in a national study continued to gain
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5 44 weight, but more slowly than 1999/2000–2004/5. While weight gain may be slowing, it does
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7 45 not appear to be affecting older men or those in more disadvantaged groups, and the same
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9 46 cannot be said for WC.
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For peer review only

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3 62 *Article summary*
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6 63 *Article focus*
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- 9 • We aimed to assess in a single cohort whether change in weight and waist
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11 circumference has changed in recent time periods, independent of age.
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14 66 *Key messages*
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- 17 • Between 2004/5–2011/2, Australian adults in this national cohort study continued to
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19 gain weight, but more slowly than 1999/2000–2004/5.
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- 22 • In contrast waist circumference gain was greater in the most recent period. Important
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24 differences were observed according to area-level socio-economic disadvantage.
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- 27 • While weight gain may be slowing, this has not been observed for older men or those
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29 in more disadvantaged groups.
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33 73 *Strengths and limitations*
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- 36 • Reliably measured data in a single nationally representative cohort in recent time
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38 periods
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- 41 • Analyses adjusted and matched for age for comparison between Periods to enable
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43 analysis of changes over time, rather than age
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- 46 • Selection and response bias may limit the generalisability of the results to the broader
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48 Australian population
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3 81 Obesity in adults has increased rapidly over the past few decades, leading to prevalence of
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5 82 over one quarter in many developed countries [1]. There is growing acceptance that strong
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7 83 preventive measures are required to stem the increasing prevalence, with a variety of
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10 84 approaches implemented, ranging from social marketing through whole of community
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12 85 interventions to regulatory strategies.

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15 86 There have been some suggestions that obesity prevention interventions in children have had
16
17 87 a positive effect, due to the observation that the prevalence of obesity is no longer increasing
18
19 88 at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity
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21 89 prevalence at two time points since 1999 [4] concluded that in more developed nations a
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23 90 likely slowing of the rate of increase in obesity prevalence was occurring in children, with a
24
25 91 possible turning point around 2000. However, trends in adults in this review generally
26
27 92 appeared to be continuing to increase. Since this review, an analysis of US adults through the
28
29 93 repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and
30
31 94 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that
32
33 95 time period in non-Hispanic white and Hispanic women, but continued increases in men and
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35 96 non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data
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37 97 suggests a continued increase in obesity prevalence in adults to 2012 [6]. However,
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39 98 prevalence data is driven by a range of factors, including migration, mortality and response
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41 99 bias. To determine whether the degree of weight gain in the population has slowed over time,
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46 100 a comparison of the rates of weight change is required.

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49 101 We aimed to analyse whether the degree of change in weight and waist circumference (WC)
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51 102 over time differed in a single cohort of adults, comparing weight and WC change in the same
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53 103 individuals between two consecutive time periods, adjusting for age. We used the national
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55 104 Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared annualised
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58 105 change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

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3 106 **METHODS**
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6 107 **Setting and Participants**
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9 108 The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based,
10
11 109 stratified-cluster survey of 11, 247 adults aged ≥ 25 years, recruited in 1999 -2000
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13 110 (AusDiab1). Methods and response rates have been described previously[7]. Five-year
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15 111 follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted
16
17 112 in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical
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19 113 examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3,
20
21 114 respectively. For this analysis we excluded participants with missing data on weight or WC
22
23 115 at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those
24
25 116 participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a
26
27 117 final sample size of 3,351. Ethics approval was obtained from the International Diabetes
28
29 118 Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented
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31 119 to participate in the study.
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36 120 All study assessments followed a similar protocol [8] [7]. Data were collected by
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38 121 interviewer-administered questionnaires on medical history, lifestyle and health behaviour.
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41 122 **Outcomes**
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44 123 Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm.
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46 124 Weight was measured without shoes, excess clothing, and items in pockets by a single
47
48 125 measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam
49
50 126 balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was
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52 127 recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior
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54 128 to each set of measurements. BMI was obtained from the calculation of weight (kg) divided
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3 129 by height (m²). Annual weight change was calculated as the difference in weight between
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5 130 AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time
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7 131 between the two consecutive surveys.
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9
10 132 Waist circumference was measured twice, halfway between the lower border of the ribs and
11
12 133 the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the
13
14 134 mean of the two closest measurements was calculated. Annualised WC change was
15
16 135 calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by
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18 136 the follow-up time between the two consecutive surveys.
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22 137 **Co-factors**

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25 138 Data on education, country of birth, smoking and physical activity and television
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27 139 viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was
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29 140 ascertained by asking if participants had been told by a doctor or nurse that they had angina,
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31 141 myocardial infarction, or stroke.
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35 142 Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than
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37 143 daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked
38
39 144 tobacco daily) combined [9] [7].
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42 145 Education level was ascertained by asking the question “Which of these describes the highest
43
44 146 qualification you have received?” Education was categorised as secondary only (comprising
45
46 147 those with a secondary school qualification), diploma (comprising nursing or teaching
47
48 148 qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor
49
50 149 degree, post-graduate diploma or masters degree/doctorate)[10].
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54 150 Area-level socio-economic disadvantage was estimated using the Index of Relative
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56 151 Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was
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3 152 developed by the Australian Bureau of Statistics, to create a summary measure from a group
4
5 153 of 20 variables (related to education, income, employment, family composition, housing
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7 154 benefits, car ownership, ethnicity, English language proficiency, residential overcrowding)
8
9
10 155 displaying dimensions of social disadvantage [11]. The index is constructed so that high
11
12 156 values reflect areas with high socio-economic status (relative advantage) and low values
13
14 157 reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage
15
16 158 were calculated amongst the final study sample.

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19 159 Physical activity was measured via an interviewer-administered Active Australia
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21 160 questionnaire, which considered participation in predominantly leisure-time physical
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23 161 activities (including walking for transport) during the previous week [12]. Total physical
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25 162 activity time was calculated as the sum of the time spent walking (if continuous and for ≥ 10
26
27 163 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-
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29 164 intensity physical activity [13].

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33 165 Self-reported television viewing time was calculated as the total time spent watching
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35 166 television or videos in the previous week, and is considered a reliable and valid estimate of
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37 167 television viewing time among adults [14].

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41 168 Average daily energy intake was assessed using a self-administered food frequency
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43 169 questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with
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45 170 additional questions on food habits, portion size and consumption of alcoholic beverages. In
46
47 171 AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the
48
49 172 state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential
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51 173 measurement error, manual blood pressure measurements were adjusted as previously
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53 174 described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.
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3 175 Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus
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5 176 Optical, Tokyo, Japan) at a central laboratory [17].
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8 177 Classification of diabetes status has been described elsewhere [17]. Briefly, participants were
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10 178 classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and
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12 179 were either taking hypoglycaemic medication or had fasting plasma glucose (FPG)
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14 180 ≥ 7.0 mmol/L or a 2-hour plasma glucose (PG) ≥ 11.1 mmol/L. Participants not reporting
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16 181 diabetes but with FPG ≥ 7.0 mmol/L or 2-hour PG ≥ 11.1 mmol/L were classified as having
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18 182 'newly diagnosed diabetes'.
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20 21 183 Statistical analysis

22
23 184 Baseline characteristics (means and proportions at AusDiab1) were compared between
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25 185 AusDiab participants with and without complete measures at AusDiab 1, 2 and 3.
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27 186 Characteristics of the included population were also compared in 2000 and 2005,
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29 187 representing the two baseline surveys for the two weight change periods.
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32 188 The difference in annualised weight and WC change in Period 1 (2000 to 2005), compared to
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34 189 Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear
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36 190 mixed models with random effects were used to analyse the association between study period
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38 191 on annual weight or WC change. This model includes random effects associated with both
39
40 192 the cluster and the units of analysis (participants) to take the clustered structure of the data
41
42 193 into account and to allow the residuals associated with the longitudinal measures on the same
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44 194 unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model
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46 195 1), additionally adjusting for smoking, education, area level disadvantage and country of birth
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48 196 (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and
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50 197 additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4).
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52 198 Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2
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54 199 for change in Period 2. Adjustment for age enables the differences in weight and WC change
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3 200 observed between the two Periods to be attributed to time rather than age. The association
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5 201 between study period and annualised weight and WC change was also analysed across sub-
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7 202 groups and interaction terms between study period with age or sex were analysed.
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10 203 The primary analyses were repeated after excluding the few participants with annual weight
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12 204 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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14 205 age group of 30–80.

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16 206 All analyses were performed in STATA (version 11.0), with statistical significance set at the
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18 207 5% level.
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209 **RESULTS**

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

215 (Table 1 here)

216 Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to
217 being five years older, the population had a higher prevalence of diabetes (predominantly
218 type 2). In both periods the average change in weight and WC was a gain. In Period 2, a
219 smaller proportion of the population gained weight and annualised weight gain was less, at
220 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser
221 weight change across the entire distribution of weight change in Period 2, with minimal
222 difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile
223 of weight change (Appendix Figure 1A). For WC, there was no difference in the crude
224 annualised change between the two periods (Table 2). In contrast to weight change, this
225 resulted from both a smaller gain in those whose WC increased and a smaller loss in those
226 whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change
227 was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

228 (Table 2 here)

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

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3 232 65–74 (Appendix Table 1). Comparison of the crude annualised WC change for matching
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5 233 age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods
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7 234 for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–
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9 235 54 and 55–64; Appendix Table 1).

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12 236 The difference in annualised weight and WC change in Period 2, compared to Period 1, was
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14 237 assessed using linear regression analysis (Table 3A). In Period 2, annualised weight gain was
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16 238 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after
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18 239 further adjustment for smoking status, education status, ethnicity, area-level socio-economic
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20 240 disadvantage, baseline BMI and diabetes status (Table 3A), nor after adjustment for TV time,
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22 241 exercise time and energy intake (results not shown).

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26 242 Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 3A),
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28 243 with suggestions of a greater difference over time in women, and those aged under 55 years
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30 244 (although no interaction tests on these factors were significant). Annualised weight gain in
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32 245 Period 2 was non-significantly less than in Period 1 for those with high educational
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34 246 attainment (borderline significant), obesity, and those from a non-English speaking
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36 247 background. No difference in annualised weight gain between the two periods was observed
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38 248 for those in the tertile of greatest area-level socio-economic disadvantage, nor for current
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40 249 smokers.

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45 250 In Period 2, annualised WC gain was 0.07 cm/year more than in Period 1 (Table 3B). This
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47 251 did not alter substantially after further adjustment for smoking status, education status, area-
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49 252 level socio-economic disadvantage, ethnicity, baseline BMI and diabetes status (Table 3B),
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51 253 nor after adjustment for TV time, exercise time and energy intake (results not shown).

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55 254 In stratified analyses no difference in annualised WC gain between the two periods was
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57 255 observed for women, those aged <55 years, those in the highest education group, those with
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3 256 normal weight nor ex-smokers. Annualised WC gain was less in Period 2 than Period 1 for
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5 257 those in the tertile of least area-level socio-economic disadvantage (-0.14cm/year 95%CI -
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7 258 .05, -0.23).

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10 259 (Table 3 here)

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13 260 For both weight and WC, there was an apparent combined sex and age effect, such that older
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15 261 men had the least favourable changes over time (Figure 1).

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18 262 The primary analyses were repeated after excluding the few participants with annual weight
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20 263 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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22 264 age group of 30–80. No differences in results were seen.

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27 28 29 266 **DISCUSSION**

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32 267 In this analysis of a single cohort of Australian adults, weight and WC increased in the most
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34 268 recent period in all population sub-groups examined. Age-adjusted annualised weight gain
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36 269 between 2005–2012 was less than between 1999/2000–2005, but annualised WC gain was
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38 270 greater. Lesser weight gain over time was not seen in older men or those with greatest area-
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40 271 level socio-economic disadvantage.

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47 273 The lack of difference in weight and WC change between the two periods observed for
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49 274 current smokers, those from a non-English speaking background and those with obesity, is
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51 275 likely to reflect small sample sizes in these groups. In general, adjustment for covariates had
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53 276 little effect on the observed associations between study period and weight and WC change.
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55 277 As time spent watching TV, exercise and energy intake might be expected to be mediating

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3 278 much of the observed changes, we had expected an observable reduction in the difference
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5 279 between study periods after adjustment for these factors. The lack of impact after adjustment
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7 280 likely reflects that they are relatively blunt instruments to detect small changes in behaviour
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9 281 over time. The self-reported nature of these behavioural questionnaires is associated with
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11 282 both differential and non-differential error [18] [19]. While validated, the FFQ is has a
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13 283 limited list of foods and is affected by the inability of individuals to accurately report their
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15 284 food intake retrospectively over a long period of time [20]. Further the Active Australia
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17 285 questionnaire only refers to leisure time activity and TV watching is only one component of
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19 286 sitting time.
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24 288 The general observation that weight gain may be lessening over time supports the cross-
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26 289 sectional time series observations of a plateau in the prevalence of obesity and rate of change
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28 290 in BMI [4]. However, these results also suggest that the general observations do not tell the
29
30 291 whole story, with large differences between different population subgroups, and a contrasting
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32 292 observation for waist circumference. The sex differences observed here are similar to the
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34 293 cross-sectional trends reported for American adults for whom a clear plateau in obesity
35
36 294 prevalence has been observed for women but not men [5]. The differences we observed
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38 295 according to level of area-level socio-economic disadvantage also reflect findings from the
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40 296 review of obesity trends in which the levelling off of obesity was generally more pronounced
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42 297 in groups with higher socio-economic position [4]. It will be important to do a similar
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44 298 analysis in a longitudinal children's cohort, as their experience is likely to differ from that of
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46 299 adults. Children have been exposed to a wide range of obesity prevention interventions,
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48 300 particularly in schools, in countries such as Australia and cross-sectional trends clearly
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50 301 suggest a plateauing in the prevalence of obesity in children [4].
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55 302 The observation that rates of WC change may be continuing to increase even as rates of
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57 303 weight change decrease may reflect prior findings using the NHANES data that WC is
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3 304 increasing to a greater extent than expected from changes in weight [21] [22]. While we
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5 305 observed changes in weight and WC to be highly correlated these results combined suggest a
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7 306 preferential increase in abdominal adiposity over time, which is thought to be associated with
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10 307 greater risk of cardio-metabolic outcomes [23]. The potential implication that current
11
12 308 bodyweight trends are leading a more metabolically active obesity, with increased risks for
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14 309 outcomes such as diabetes, hypertension and cardiovascular disease warrants further
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16 310 investigation.

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19 311 The key strength of the current study is that for the first time it addresses this important
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21 312 question through an analysis of the same cohort of adults over two distinct but recent time
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23 313 periods, independent of the effects of ageing. In doing this, conclusions can be drawn about
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25 314 the changes over time independent of unmeasurable differences in cohorts. Other strengths
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28 315 include the national population sampling strategy of the AusDiab cohort and the measured
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30 316 weight and WC at each study wave.

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33 317 The potential limitation of the current study is the lack of generalisability of the included
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35 318 cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who
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37 319 attended all three waves are more select again, with higher educational attainment and a
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39 320 lower prevalence of chronic disease and risk factors. It is possible that a generally more
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41 321 healthy and health conscious population has a stronger response to population health
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43 322 messages, and consequently the lesser weight gain observed here in consecutive age cohorts
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45 323 over time may be greater than would be observed for the general population. However, the
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47 324 current observations lend support to the concept that weight gain is decreasing over time in
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49 325 the population, even if the AusDiab cohort represents a particularly sensitive indicator. One
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51 326 further potential limitation is the use of different weighing scales at AusDiab 2 and 3
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53 327 compared to AusDiab1. Although all scales were calibrated in the same way at each survey
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3 328 wave, differences in variability between the scales may have led to more variability in the
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5 329 change in weight in Period 1 than Period 2.
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8 330 The results also suggest there is no room for complacency in obesity prevention. The rates of
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10 331 overweight and obesity remain high, the average change in weight and WC remains an
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12 332 increase and there is no reduction in the rate of WC gain. Further, no decrease in the rate of
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14 333 weight or WC change were observed in older men. Finally, the observation that no decrease
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16 334 in rates of weight and WC change is being seen by those living in the most socially
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18 335 disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the
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20 336 social inequalities in obesity, and consequent ill health [24]. It is critical that further studies
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22 337 are conducted to confirm these findings and that we work to identify the causes of the
23
24 338 observed changes, including the differences observed in specific population sub-groups.
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29 339 In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a
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31 340 faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While weight
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33 341 gain may be slowing, it does not appear to be affecting older men or those in more
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35 342 disadvantaged groups, and the same cannot be said for WC.
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3 347 **Acknowledgements**
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10 350 ***Data sharing***
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16 352 ***Authorship statement***
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18 353 AP conceived of the article, executed the analysis and writing of the article and is guarantor
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20 354 for the article. JS, DM and KB contributed to the ideas included within and writing of the
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22 355 article, and provision of data. PZ contributed to the writing of the article and provision of
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378 **References**

- 379 1. International Association for the Study of Obesity. Obesity the global epidemic. Secondary Obesity
380 the global epidemic 2013. <http://www.iaso.org/iotf/obesity/obesitytheglobalepidemic/>.
- 381 2. Stamatakis E, Zaninotto P, Falaschetti E, Mindell J, Head J. Time trends in childhood and
382 adolescent obesity in England from 1995 to 2007 and projections of prevalence to 2015. *J*
383 *Epidemiol Community Health* 2010;64(2):167-74 doi: 10.1136/jech.2009.098723[published
384 Online First: Epub Date]].
- 385 3. Sundblom E, Petzold M, Rasmussen F, Callmer E, Lissner L. Childhood overweight and obesity
386 prevalences levelling off in Stockholm but socioeconomic differences persist. *Int J Obes*
387 (Lond) 2008;32(10):1525-30 doi: 10.1038/ijo.2008.104[published Online First: Epub Date]].
- 388 4. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the year 1999--a
389 review of evidence and perspectives. *Obes Rev* 2010;11(12):835-46 doi: 10.1111/j.1467-
390 789X.2010.00810.x[published Online First: Epub Date]].
- 391 5. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of
392 body mass index among US adults, 1999-2010. *JAMA* 2012;307(5):491-7 doi:
393 10.1001/jama.2012.39[published Online First: Epub Date]].
- 394 6. Statistics ABo. Australian Health Survey: First Results, 2011-12. Canberra: Australian Bureau of
395 Statistics, 2012.
- 396 7. Dunstan DW, Zimmet PZ, Welborn TA, et al. The Australian Diabetes, Obesity and Lifestyle Study
397 (AusDiab)--methods and response rates. *Diabetes Res Clin Pract* 2002;57(2):119-29
- 398 8. Cameron AJ, Welborn TA, Zimmet PZ, et al. Overweight and obesity in Australia: the 1999-2000
399 Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Med J Aust* 2003;178(9):427-32
- 400 9. Risk Factor Prevalence Management Committee. Risk factor prevalence study No.3, 1989:
401 National Heart Foundation and Australian Institute of Health, 1990.
- 402 10. Williams ED, Magliano DJ, Zimmet PZ, et al. Area-level socioeconomic status and incidence of
403 abnormal glucose metabolism: the Australian Diabetes, Obesity and Lifestyle (AusDiab)
404 study. *Diabetes Care* 2012;35(7):1455-61 doi: 10.2337/dc11-1410[published Online First:
405 Epub Date]].
- 406 11. Statistics ABo. Information Paper - Census of Population and Housing: Socio-Economic Indexes
407 for Areas Australia 2001. : Australian Bureau of Statistics, 2001.
- 408 12. Australian Institute of Health and Welfare. The Active Australia Survey. A guide and manual for
409 implementation, analysis and reporting. Canberra: Australian Institute of Health and
410 Welfare, 2003.
- 411 13. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results of the
412 1999 National Physical Activity Survey. Australian Institute of Health and Welfare cat No
413 CVD10. Canberra: Australian Institute of Health and Welfare, 2000.
- 414 14. Salmon J, Bauman A, Crawford D, Timperio A, Owen N. The association between television
415 viewing and overweight among Australian adults participating in varying levels of leisure-
416 time physical activity. *Int. J. Obes. Relat. Metab. Disord.* 2000;24:600-6
- 417 15. Ireland P, Jolley D, Giles G, et al. Development of the Melbourne FFQ: A food frequency
418 questionnaire for use in an Australian prospective study involving an ethnically diverse
419 cohort. *Asia Pacific J Clin Nutr* 1994;3:19-31
- 420 16. Briganti EM, Shaw JE, Chadban SJ, et al. Untreated hypertension among Australian adults: the
421 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Med J Aust*
422 2003;179(3):135-9
- 423 17. Magliano DJ, Barr EL, Zimmet PZ, et al. Glucose indices, health behaviors, and incidence of
424 diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle Study. *Diabetes Care*
425 2008;31(2):267-72 doi: 10.2337/dc07-0912[published Online First: Epub Date]].

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2
3 426 18. Hebert JR, Hurley TG, Peterson KE, et al. Social desirability trait influences on self-reported
4 427 dietary measures among diverse participants in a multicenter multiple risk factor trial. *J Nutr*
5 428 2008;138(1):226S-34S
6 429 19. Booth ML, Owen N, Bauman AE, Gore CJ. Retest reliability of recall measures of leisure-time
7 430 physical activity in Australian adults. *Int J Epidemiol* 1996;25(1):153-9
8 431 20. Dodd KW, Guenther PM, Freedman LS, et al. Statistical methods for estimating usual intake of
9 432 nutrients and foods: a review of the theory. *J Am Diet Assoc* 2006;106(10):1640-50 doi:
10 433 10.1016/j.jada.2006.07.011[published Online First: Epub Date]].
11 434 21. Elobeid MA, Desmond RA, Thomas O, Keith SW, Allison DB. Waist circumference values are
12 435 increasing beyond those expected from BMI increases. *Obesity (Silver Spring)*
13 436 2007;15(10):2380-3 doi: 15/10/2380 [pii]10.1038/oby.2007.282[published Online First: Epub
14 437 Date]].
15
16 438 22. Walls HL, Stevenson CE, Mannan HR, et al. Comparing trends in BMI and waist circumference.
17 439 *Obesity (Silver Spring)* 2011;19(1):216-9 doi: oby2010149 [pii
18 440 10.1038/oby.2010.149[published Online First: Epub Date]].
19
20 441 23. Welborn TA, Dhaliwal SS, Bennett SA. Waist-hip ratio is the dominant risk factor predicting
21 442 cardiovascular death in Australia. *Med J Aust* 2003;179(11-12):580-5
22 443 24. Backholer K, Mannan HR, Magliano D, et al. Projected socioeconomic disparities in the
23 444 prevalence of obesity amongst Australian adults. *Australian and New Zealand Journal of*
24 445 *Public Health* 2012;in press
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449 Figures

450 Figure 1. Difference in annualised change in weight (kg/year) or waist circumference

451 (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

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3 457 Tables
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6 458 Table 1 Comparison of characteristics in 1999/2000 between the included and excluded
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8 459 population
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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

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38 460 Notes: data are % or mean (SD) *Indicates a significant difference (p<0.05)
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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)

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5	disadvantage				
6	Area level disadvantage-				
7	middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31-- 0.14)*	-0.22 (-0.31--0.14)*
8					
9	Area level disadvantage-				
10	tertile of least	1125	0.30 (0.24-0.35)	-0.08 (-0.16-- 0.01)*	-0.08 (-0.15--0.00)*
11	disadvantage				
12	Normal weight				
13		1342	0.4 (0.36-0.44)	-0.07 (-0.13-- 0.01)*	-0.07 (-0.13--0.01)*
14					
15	Overweight				
16		1375	0.31 (0.26-0.37)	-0.12 (-0.18-- 0.05)*	-0.11 (-0.18--0.04)*
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18	Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*
19					
20	English speaking				
21	country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15-- 0.06)*	-0.1 (-0.15--0.05)*
22					
23	Non-English speaking	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)
24	country of birth				
25	Never smokers				
26		2121	0.34 (0.29-0.38)	-0.10 (-0.15-- 0.04)*	-0.1 (-0.15--0.04)*
27					
28	Ex smokers				
29		894	0.27 (0.20-0.34)	-0.15 (-0.24-- 0.06)*	-0.15 (-0.24--0.06)*
30					
31	Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)
32					
33	No chronic disease#				
34		1944	0.42 (0.37-0.47)	-0.10 (-0.16-- 0.04)*	-0.10 (-0.16--0.04)*
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	Sample size	Annualised WC change in Period 1	Model 1	Model 2	Model 3
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)					
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)*

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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

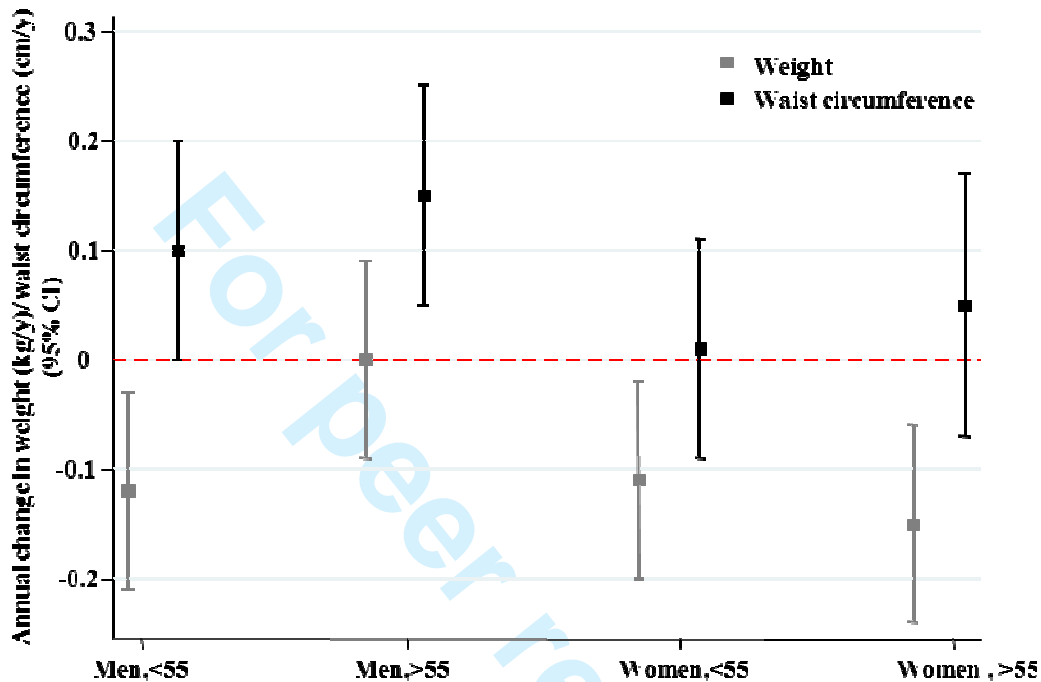
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

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.

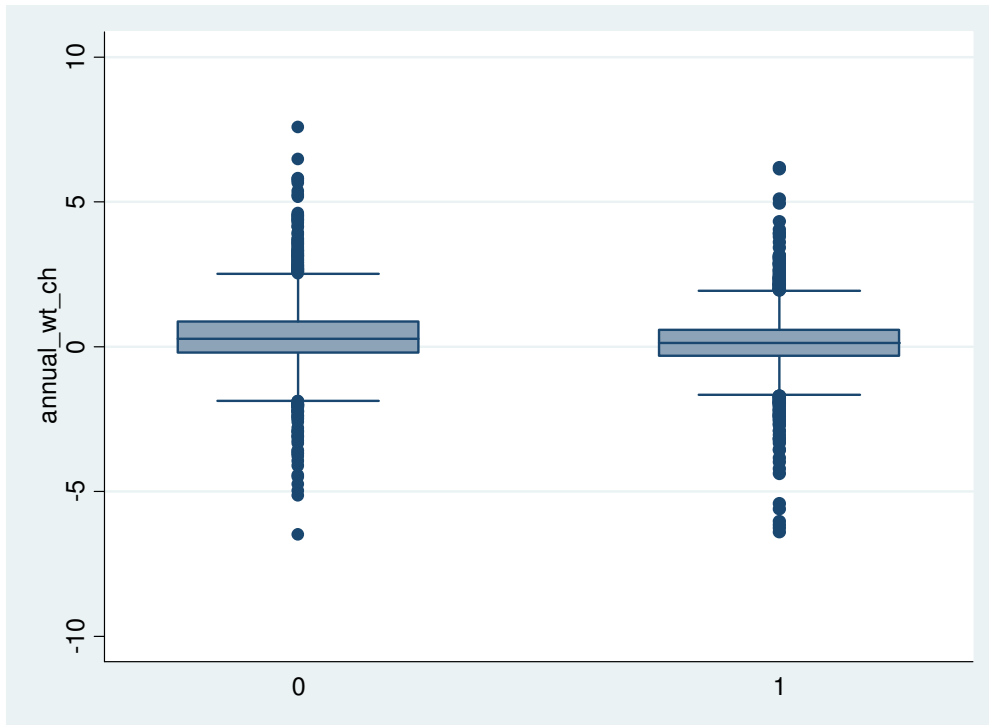


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Appendix

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

A. Annualised weight change



B. Annualised waist circumference change

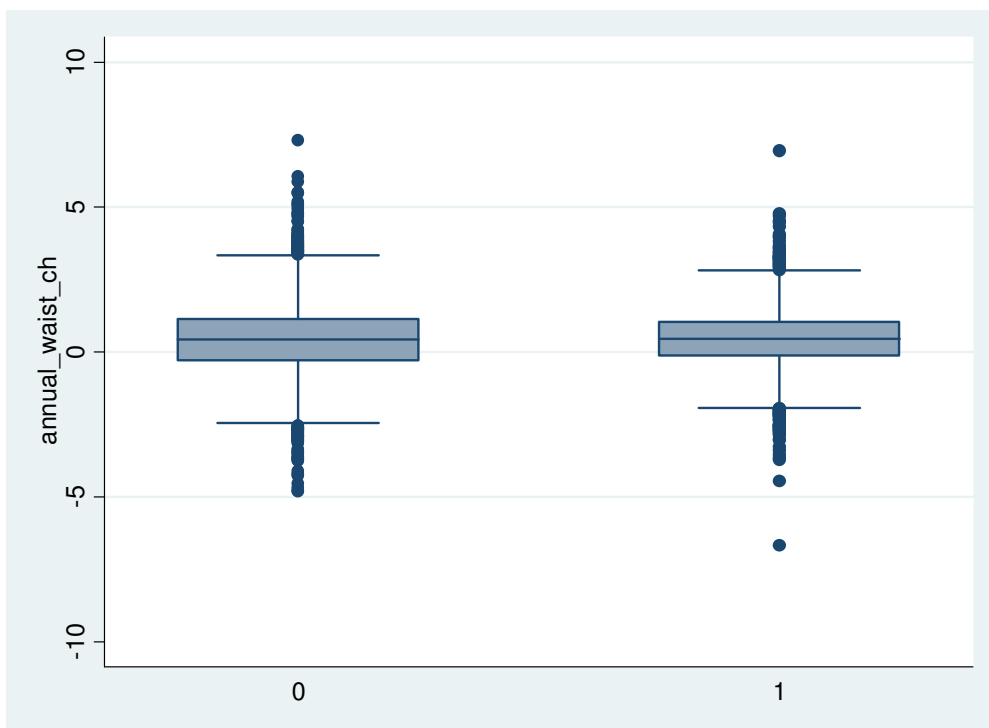


Table 1 Comparison of annualised weight and waist circumference change between Period 1 and Period 2 for matching age groups.

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 ($p < 0.05$)

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

2

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15 24 AP conceived of the article, executed the analysis and writing of the article and is guarantor
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17 25 for the article. JS, DM and KB contributed to the ideas included within and writing of the
18
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3 49 *Article summary*
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6 50 *Article focus*
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- 9 • We aimed to assess in a single cohort whether change in weight and waist
10
11 circumference has changed in recent time periods, **independent of age**.
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14 53 *Key messages*
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- 17 • Between 2004/5–2011/2, Australian adults in this national cohort study continued to
18
19 gain weight, but more slowly than 1999/2000–2004/5.
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- 22 • In contrast waist circumference gain was greater in the most recent period. Important
23
24 differences were observed according to area-level **socio-economic** disadvantage.
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- 27 • **While weight gain may be slowing, this has not been observed for older men or**
28
29 **those in more disadvantaged groups.**
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33 60 *Strengths and limitations*
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- 36 • Reliably measured data in a single nationally representative cohort in recent time
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38 periods
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- 41 • **Analyses adjusted and matched for age for comparison between Periods to**
42
43 **enable analysis of changes over time, rather than age**
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- 46 • Selection and response bias may limit the generalisability of the results to the broader
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48 Australian population
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68 **ABSTRACT**

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

71 Design: Longitudinal cohort study with three surveys, 1 – 1999/2000; 2 – 2004/2005; 3 –
72 2011/2012. Generalized linear mixed models with random effects were used to compare
73 **annualised** weight and WC change between surveys 1 and 2 (Period 1) with that between
74 surveys 2 and 3 (Period 2). **Models were adjusted for age to analyse changes with time**
75 **rather than age**. Models were additionally adjusted for sex, education status, area-level
76 **socio-economic** disadvantage, ethnicity, body mass index, diabetes status, and smoking
77 status.

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

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

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

85 Results: Mean weight and WC increased in both Periods. **Annualised** weight gain in Period
86 2 was 0.11kg/year (95% CI 0.06–0.15) less than in Period 1. **Lesser** annual weight gain
87 between the two periods was not seen for those with greatest area-level **socio-economic**
88 disadvantage, or in men over the age of 55. In contrast, the **annualised** WC increase in
89 Period 2 was greater than in Period 1 (0.07cm/year, 95% CI 0.01–0.12). **The increase was**
90 **greatest in males 55+ and those with greater area-level socio-economic disadvantage.**

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3 91 Conclusions: Between 2004/5–2011/2, Australian adults in a national study continued to gain
4
5 92 weight, but more slowly than 1999/2000–2004/5. **While weight gain may be slowing, it**
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7 93 **does not appear to be affecting older men or those in more disadvantaged groups, and**
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10 94 **the same cannot be said for WC.**

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For peer review only

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3 96 Obesity in adults has increased rapidly over the past few decades, leading to prevalence of
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5 97 over one quarter in many developed countries [1]. There is growing acceptance that strong
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7 98 preventive measures are required to stem the increasing prevalence, with a variety of
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10 99 approaches implemented, ranging from social marketing through whole of community
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12 100 interventions to regulatory strategies.

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15 101 There have been some suggestions that obesity prevention interventions in children have had
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17 102 a positive effect, due to the observation that the prevalence of obesity is no longer increasing
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19 103 at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity
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21 104 prevalence at two time points since 1999 [4] concluded that in more developed nations a
22
23 105 likely slowing of the rate of increase in obesity prevalence was occurring in children, with a
24
25 106 possible turning point around 2000. However, trends in adults in this review generally
26
27 107 appeared to be continuing to increase. Since this review, an analysis of US adults through the
28
29 108 repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and
30
31 109 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that
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33 110 time period in non-Hispanic white and Hispanic women, but continued increases in men and
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35 111 non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data
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37 112 suggests a continued increase in obesity prevalence in adults to 2012 [6]. However,
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39 113 prevalence data is driven by a range of factors, including migration, mortality and response
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41 114 bias. To determine whether the degree of weight gain in the population has slowed over time,
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43 115 a comparison of the rates of weight change is required.
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49 116 We aimed to analyse whether the degree of change in weight and waist circumference (WC)
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51 117 over time differed in a single cohort of adults, comparing weight and WC change in the same
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53 118 individuals between two consecutive time periods, **adjusting for age**. We used the national
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55 119 Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared **annualised**
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57 120 change in weight and WC between 2000 and 2005 to that between 2005 and 2012.
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3 121 **METHODS**
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6 122 **Setting and Participants**
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9 123 The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based,
10
11 124 stratified-cluster survey of 11, 247 adults aged ≥ 25 years, recruited in 1999 -2000
12
13 125 (AusDiab1). Methods and response rates have been described previously[7]. Five-year
14
15 126 follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted
16
17 127 in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical
18
19 128 examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3,
20
21 129 respectively. For this analysis we excluded participants with missing data on weight or WC
22
23 130 at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those
24
25 131 participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a
26
27 132 final sample size of 3,351. Ethics approval was obtained from the International Diabetes
28
29 133 Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented
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31 134 to participate in the study.
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36 135 All study assessments followed a similar protocol [8] [7]. Data were collected by
37
38 136 interviewer-administered questionnaires on medical history, lifestyle and health behaviour.
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41 137 **Outcomes**
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44 138 Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm.
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46 139 Weight was measured without shoes, excess clothing, and items in pockets by a single
47
48 140 measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam
49
50 141 balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was
51
52 142 recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior
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54 143 to each set of measurements. BMI was obtained from the calculation of weight (kg) divided
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3 144 by height (m²). Annual weight change was calculated as the difference in weight between
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5 145 AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time
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7 146 between the two consecutive surveys.
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10 147 Waist circumference was measured twice, halfway between the lower border of the ribs and
11
12 148 the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the
13
14 149 mean of the two closest measurements was calculated. **Annualised** WC change was
15
16 150 calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by
17
18 151 the follow-up time between the two consecutive surveys.
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22 152 **Co-factors**

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25 153 Data on education, country of birth, smoking and physical activity and television
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27 154 viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was
28
29 155 ascertained by asking if participants had been told by a doctor or nurse that they had angina,
30
31 156 myocardial infarction, or stroke.
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35 157 Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than
36
37 158 daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked
38
39 159 tobacco daily) combined [9] [7].
40
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42 160 Education level was ascertained by asking the question “Which of these describes the highest
43
44 161 qualification you have received?” Education was categorised as secondary only (comprising
45
46 162 those with a secondary school qualification), diploma (comprising nursing or teaching
47
48 163 qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor
49
50 164 degree, post-graduate diploma or masters degree/doctorate)[10].
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54 165 Area-level **socio-economic** disadvantage was estimated using the Index of Relative
55
56 166 Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was
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3 167 developed by the Australian Bureau of Statistics, to create a summary measure from a group
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5 168 of 20 variables (related to education, income, employment, family composition, housing
6
7 169 benefits, car ownership, ethnicity, English language proficiency, residential overcrowding)
8
9
10 170 displaying dimensions of social disadvantage [11]. The index is constructed so that high
11
12 171 values reflect areas with high socio-economic status (relative advantage) and low values
13
14 172 reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage
15
16 173 were calculated amongst the final study sample.

17
18
19 174 Physical activity was measured via an interviewer-administered Active Australia
20
21 175 questionnaire, which considered participation in predominantly leisure-time physical
22
23 176 activities (including walking for transport) during the previous week [12]. Total physical
24
25 177 activity time was calculated as the sum of the time spent walking (if continuous and for ≥ 10
26
27 178 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-
28
29 179 intensity physical activity [13].

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33 180 Self-reported television viewing time was calculated as the total time spent watching
34
35 181 television or videos in the previous week, and is considered a reliable and valid estimate of
36
37 182 television viewing time among adults [14].

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41 183 Average daily energy intake was assessed using a self-administered food frequency
42
43 184 questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with
44
45 185 additional questions on food habits, portion size and consumption of alcoholic beverages. In
46
47 186 AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the
48
49 187 state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential
50
51 188 measurement error, manual blood pressure measurements were adjusted as previously
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53 189 described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.
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3 190 Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus
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5 191 Optical, Tokyo, Japan) at a central laboratory [17].
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8 192 Classification of diabetes status has been described elsewhere [17]. Briefly, participants were
9
10 193 classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and
11
12 194 were either taking hypoglycaemic medication or had fasting plasma glucose (FPG)
13
14 195 ≥ 7.0 mmol/L or a 2-hour plasma glucose (PG) ≥ 11.1 mmol/L. Participants not reporting
15
16 196 diabetes but with FPG ≥ 7.0 mmol/L or 2-hour PG ≥ 11.1 mmol/L were classified as having
17
18 197 'newly diagnosed diabetes'.
19

20 198 **Statistical analysis**

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23 199 Baseline characteristics (means and proportions at AusDiab1) were compared between
24
25 200 AusDiab participants with and without complete measures at AusDiab 1, 2 and 3.
26
27 201 Characteristics of the included population were also compared in 2000 and 2005,
28
29 202 representing the two baseline surveys for the two weight change periods.
30
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32 203 The difference in **annualised** weight and WC change in Period 1 (2000 to 2005), compared
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34 204 to Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear
35
36 205 mixed models with random effects were used to analyse the association between study period
37
38 206 on annual weight or WC change. This model includes random effects associated with both
39
40 207 the cluster and the units of analysis (participants) to take the clustered structure of the data
41
42 208 into account and to allow the residuals associated with the longitudinal measures on the same
43
44 209 unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model
45
46 210 1), additionally adjusting for smoking, education, area level disadvantage and country of birth
47
48 211 (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and
49
50 212 additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4).
51
52 213 Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2
53
54 214 for change in Period 2. **Adjustment for age enables the differences in weight and WC**
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3 215 **change observed between the two Periods to be attributed to time rather than age.** The
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5 216 association between study period and **annualised** weight and WC change was also analysed
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7 217 across sub-groups and interaction terms between study period with age or sex were analysed.
8
9 218 The primary analyses were repeated after excluding the few participants with annual weight
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11 219 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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13 220 age group of 30–80.
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16 221 All analyses were performed in STATA (version 11.0), with statistical significance set at the
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18 222 5% level.
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224 **RESULTS**

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

230 (Table 1 here)

231 Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to
232 being five years older, the population had a higher prevalence of diabetes (predominantly
233 type 2). In both periods the average change in weight and WC was a gain. In Period 2, a
234 smaller proportion of the population gained weight and **annualised** weight gain was less, at
235 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser
236 weight change across the entire distribution of weight change in Period 2, with minimal
237 difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile
238 of weight change (Appendix Figure 1A). For WC, there was no difference in the crude
239 **annualised** change between the two periods (Table 2). In contrast to weight change, this
240 resulted from both a smaller gain in those whose WC increased and a smaller loss in those
241 whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change
242 was 0.69 (0.68 in Period 1, and 0.71 in Period 2).

243 (Table 2 here)

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

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3 247 65–74 (Appendix Table 1). Comparison of the crude **annualised** WC change for matching
4
5 248 age-groups in Periods 1 and 2 indicated no difference in WC gain between the two periods
6
7 249 for women and a generally larger WC gain in Period 2 for men (significant for men aged 45–
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10 250 54 and 55–64; Appendix Table 1).

11
12 251 The difference in **annualised** weight and WC change in Period 2, compared to Period 1, was
13
14 252 assessed using linear regression analysis (Table 3A). In Period 2, **annualised** weight gain
15
16 253 was 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially
17
18 254 after further adjustment for smoking status, education status, ethnicity, area-level **socio-**
19
20 255 **economic** disadvantage, baseline BMI and diabetes status (Table 3A), nor after adjustment
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22 256 for TV time, exercise time and energy intake (results not shown).

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27 257 **Annualised** weight gain in Period 2 was less than in Period 1 for most sub-groups (Table
28
29 258 3A), with suggestions of a greater difference over time in women, and those aged under 55
30
31 259 years (although no interaction tests on these factors were significant). Annualised weight gain
32
33 260 in Period 2 was non-significantly less than in Period 1 for those with high educational
34
35 261 attainment (borderline significant), obesity, and those from a non-English speaking
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37 262 background. No difference in **annualised** weight gain between the two periods was observed
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39 263 for those in the tertile of greatest area-level **socio-economic** disadvantage, nor for current
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41 264 smokers.

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45 265 In Period 2, **annualised** WC gain was 0.07 cm/year more than in Period 1 (Table 3B). This
46
47 266 did not alter substantially after further adjustment for smoking status, education status, area-
48
49 267 level **socio-economic** disadvantage, ethnicity, baseline BMI and diabetes status (Table 3B),
50
51 268 nor after adjustment for TV time, exercise time and energy intake (results not shown).

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55 269 In stratified analyses no difference in **annualised** WC gain between the two periods was
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57 270 observed for women, those aged <55 years, those in the highest education group, those with
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3 271 normal weight nor ex-smokers. **Annualised** WC gain was less in Period 2 than Period 1 for
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5 272 those in the tertile of least area-level **socio-economic** disadvantage (-0.14cm/year 95%CI -
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7 273 .05, -0.23).

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10 274 (Table 3 here)

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13 275 For both weight and WC, there was an apparent combined sex and age effect, such that older
14
15 276 men had the least favourable changes over time (Figure 1).

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18 277 The primary analyses were repeated after excluding the few participants with annual weight
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20 278 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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22 279 age group of 30–80. No differences in results were seen.

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30 31 32 282 **DISCUSSION**

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35 283 In this analysis of a single cohort of Australian adults, weight and WC increased in the most
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37 284 recent period in all population sub-groups examined. **Age-adjusted annualised** weight gain
38
39 285 between 2005–2012 was less than between 1999/2000–2005, but **annualised** WC gain was
40
41 286 greater. **Lesser weight gain** over time was not seen in older men or those with greatest area-
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43 287 level **socio-economic** disadvantage.

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50 289 The lack of difference in weight and WC change between the two periods observed for
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52 290 current smokers, those from a non-English speaking background and those with obesity, is
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54 291 likely to reflect small sample sizes in these groups. In general, adjustment for covariates had
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56 292 little effect on the observed associations between study period and weight and WC change.

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3 293 As time spent watching TV, exercise and energy intake might be expected to be mediating
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5 294 much of the observed changes, we had expected **an observable reduction in the difference**
6
7 295 **between study periods** after adjustment for these factors. The lack of impact after
8
9 296 adjustment likely reflects that they are relatively blunt instruments to detect small changes in
10
11 297 behaviour over time. **The self-reported nature of these behavioural questionnaires is**
12
13 298 **associated with both differential and non-differential error [18] [19]. While validated,**
14
15 299 **the FFQ is has a limited list of foods and is affected by the inability of individuals to**
16
17 300 **accurately report their food intake retrospectively over a long period of time [20].**
18
19 301 **Further the Active Australia questionnaire only refers to leisure time activity and TV**
20
21 302 **watching is only one component of sitting time.**
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23 303
24 304 The general observation that weight gain may be lessening over time supports the cross-
25
26 305 sectional time series observations of a plateau in the prevalence of obesity and rate of change
27
28 306 in BMI [4]. However, these results also suggest that the general observations do not tell the
29
30 307 whole story, with large differences between different population subgroups, and a contrasting
31
32 308 observation for waist circumference. The sex differences observed here are similar to the
33
34 309 cross-sectional trends reported for American adults for whom a clear plateau in obesity
35
36 310 prevalence has been observed for women but not men [5]. The differences we observed
37
38 311 according to level of area-level **socio-economic** disadvantage also reflect findings from the
39
40 312 review of obesity trends in which the levelling off of obesity was generally more pronounced
41
42 313 in groups with higher socio-economic position [4]. **It will be important to do a similar**
43
44 314 **analysis in a longitudinal children's cohort, as their experience is likely to differ from**
45
46 315 **that of adults. Children have been exposed to a wide range of obesity prevention**
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48 316 **interventions, particularly in schools, in countries such as Australia and cross-sectional**
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50 317 **trends clearly suggest a plateauing in the prevalence of obesity in children [4].**
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3 318 The observation that rates of WC change may be continuing to increase even as rates of
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5 319 weight change decrease may reflect prior findings using the NHANES data that WC is
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7 320 increasing to a greater extent than expected from changes in weight [21] [22]. While we
8
9 321 observed changes in weight and WC to be highly correlated these results combined suggest a
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11 322 preferential increase in abdominal adiposity over time, which is thought to be associated with
12
13 323 greater risk of cardio-metabolic outcomes [23]. The potential implication that current
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15 324 bodyweight trends are leading a more metabolically active obesity, with increased risks for
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17 325 outcomes such as diabetes, hypertension and cardiovascular disease warrants further
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19 326 investigation.

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24 327 The key strength of the current study is that for the first time it addresses this important
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26 328 question through an analysis of the same cohort of adults over two distinct but recent time
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28 329 periods, **independent of the effects of ageing**. In doing this, conclusions can be drawn about
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30 330 the changes over time independent of unmeasurable differences in cohorts. Other strengths
31
32 331 include the national population sampling strategy of the AusDiab cohort and the measured
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34 332 weight and WC at each study wave.

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38 333 The potential limitation of the current study is the lack of generalisability of the included
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40 334 cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who
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42 335 attended all three waves are more select again, with higher educational attainment and a
43
44 336 lower prevalence of chronic disease and risk factors. It is possible that a generally more
45
46 337 healthy and health conscious population has a stronger response to population health
47
48 338 messages, and consequently the **lesser weight gain observed here in consecutive age**
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50 339 **cohorts over time** may be greater than would be observed for the general population.
51
52 340 However, the current observations lend support to the concept that weight gain is decreasing
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54 341 over time in the population, even if the AusDiab cohort represents a particularly sensitive
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56 342 indicator. One further potential limitation is the use of different weighing scales at AusDiab 2
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3 343 and 3 compared to AusDiab1. **Although all scales were calibrated in the same way at each**
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5 344 **survey wave, differences in variability between the scales may have led to more**
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7 345 **variability in the change in weight in Period 1 than Period 2.**
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10 346 The results also suggest there is no room for complacency in obesity prevention. The rates of
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12 347 overweight and obesity remain high, the average change in weight and WC remains an
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14 348 increase and there is no reduction in the **rate of WC** gain. Further, no **decrease** in the rate of
15
16 349 weight or WC change were observed in older men. Finally, the observation that no **decrease**
17
18 350 in rates of weight and WC change is being seen by those living in the most socially
19
20 351 disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the
21
22 352 social inequalities in obesity, and consequent ill health [24]. It is critical that further studies
23
24 353 are conducted to confirm these findings and that we work to identify the causes of the
25
26 354 observed changes, **including the differences observed in specific** population sub-groups.
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31 355 In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a
32
33 356 faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. **While weight**
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35 357 **gain may be slowing, it does not appear to be affecting older men or those in more**
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37 358 **disadvantaged groups, and the same cannot be said for WC.**
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4

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6

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367 **References**

- 368 1. International Association for the Study of Obesity. Obesity the global epidemic. Secondary Obesity
369 the global epidemic 2013. <http://www.iaso.org/iotf/obesity/obesitytheglobalepidemic/>.
- 370 2. Stamatakis E, Zaninotto P, Falaschetti E, Mindell J, Head J. Time trends in childhood and
371 adolescent obesity in England from 1995 to 2007 and projections of prevalence to 2015. *J*
372 *Epidemiol Community Health* 2010;**64**(2):167-74 doi: 10.1136/jech.2009.098723[published
373 Online First: Epub Date]].
- 374 3. Sundblom E, Petzold M, Rasmussen F, Callmer E, Lissner L. Childhood overweight and obesity
375 prevalences levelling off in Stockholm but socioeconomic differences persist. *Int J Obes*
376 (Lond) 2008;**32**(10):1525-30 doi: 10.1038/ijo.2008.104[published Online First: Epub Date]].
- 377 4. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the year 1999--a
378 review of evidence and perspectives. *Obes Rev* 2010;**11**(12):835-46 doi: 10.1111/j.1467-
379 789X.2010.00810.x[published Online First: Epub Date]].
- 380 5. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the distribution of
381 body mass index among US adults, 1999-2010. *JAMA* 2012;**307**(5):491-7 doi:
382 10.1001/jama.2012.39[published Online First: Epub Date]].
- 383 6. Statistics ABo. Australian Health Survey: First Results, 2011-12. Canberra: Australian Bureau of
384 Statistics, 2012.
- 385 7. Dunstan DW, Zimmet PZ, Welborn TA, et al. The Australian Diabetes, Obesity and Lifestyle Study
386 (AusDiab)--methods and response rates. *Diabetes Res Clin Pract* 2002;**57**(2):119-29
- 387 8. Cameron AJ, Welborn TA, Zimmet PZ, et al. Overweight and obesity in Australia: the 1999-2000
388 Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Med J Aust* 2003;**178**(9):427-32
- 389 9. Risk Factor Prevalence Management Committee. Risk factor prevalence study No.3, 1989:
390 National Heart Foundation and Australian Institute of Health, 1990.
- 391 10. Williams ED, Magliano DJ, Zimmet PZ, et al. Area-level socioeconomic status and incidence of
392 abnormal glucose metabolism: the Australian Diabetes, Obesity and Lifestyle (AusDiab)
393 study. *Diabetes Care* 2012;**35**(7):1455-61 doi: 10.2337/dc11-1410[published Online First:
394 Epub Date]].
- 395 11. Statistics ABo. Information Paper - Census of Population and Housing: Socio-Economic Indexes
396 for Areas Australia 2001. : Australian Bureau of Statistics, 2001.
- 397 12. Australian Institute of Health and Welfare. The Active Australia Survey. A guide and manual for
398 implementation, analysis and reporting. Canberra: Australian Institute of Health and
399 Welfare, 2003.
- 400 13. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results of the
401 1999 National Physical Activity Survey. Australian Institute of Health and Welfare cat No
402 CVD10. Canberra: Australian Institute of Health and Welfare, 2000.
- 403 14. Salmon J, Bauman A, Crawford D, Timperio A, Owen N. The association between television
404 viewing and overweight among Australian adults participating in varying levels of leisure-
405 time physical activity. *Int. J. Obes. Relat. Metab. Disord.* 2000;**24**:600-6
- 406 15. Ireland P, Jolley D, Giles G, et al. Development of the Melbourne FFQ: A food frequency
407 questionnaire for use in an Australian prospective study involving an ethnically diverse
408 cohort. *Asia Pacific J Clin Nutr* 1994;**3**:19-31
- 409 16. Briganti EM, Shaw JE, Chadban SJ, et al. Untreated hypertension among Australian adults: the
410 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Med J Aust*
411 2003;**179**(3):135-9
- 412 17. Magliano DJ, Barr EL, Zimmet PZ, et al. Glucose indices, health behaviors, and incidence of
413 diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle Study. *Diabetes Care*
414 2008;**31**(2):267-72 doi: 10.2337/dc07-0912[published Online First: Epub Date]].

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2
3 415 18. Hebert JR, Hurley TG, Peterson KE, et al. Social desirability trait influences on self-reported
4 416 dietary measures among diverse participants in a multicenter multiple risk factor trial. *J Nutr*
5 417 2008;**138**(1):226S-34S
6 418 19. Booth ML, Owen N, Bauman AE, Gore CJ. Retest reliability of recall measures of leisure-time
7 419 physical activity in Australian adults. *Int J Epidemiol* 1996;**25**(1):153-9
8 420 20. Dodd KW, Guenther PM, Freedman LS, et al. Statistical methods for estimating usual intake of
9 421 nutrients and foods: a review of the theory. *J Am Diet Assoc* 2006;**106**(10):1640-50 doi:
10 422 10.1016/j.jada.2006.07.011[published Online First: Epub Date]].
11 423 21. Elobeid MA, Desmond RA, Thomas O, Keith SW, Allison DB. Waist circumference values are
12 424 increasing beyond those expected from BMI increases. *Obesity (Silver Spring)*
13 425 2007;**15**(10):2380-3 doi: 15/10/2380 [pii]10.1038/oby.2007.282[published Online First: Epub
14 426 Date]].
15
16 427 22. Walls HL, Stevenson CE, Mannan HR, et al. Comparing trends in BMI and waist circumference.
17 428 *Obesity (Silver Spring)* 2011;**19**(1):216-9 doi: oby2010149 [pii
18 429 10.1038/oby.2010.149[published Online First: Epub Date]].
19
20 430 23. Welborn TA, Dhaliwal SS, Bennett SA. Waist-hip ratio is the dominant risk factor predicting
21 431 cardiovascular death in Australia. *Med J Aust* 2003;**179**(11-12):580-5
22 432 24. Backholer K, Mannan HR, Magliano D, et al. Projected socioeconomic disparities in the
23 433 prevalence of obesity amongst Australian adults. *Australian and New Zealand Journal of*
24 434 *Public Health* 2012;**in press**

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438 **Figures**

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

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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)

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5	disadvantage				
6	Area level disadvantage-				
7	middle tertile	1130	0.40 (0.34-0.47)	-0.23 (-0.31-- 0.14)*	-0.22 (-0.31--0.14)*
8					
9	Area level disadvantage-				
10	tertile of least	1125	0.30 (0.24-0.35)	-0.08 (-0.16-- 0.01)*	-0.08 (-0.15--0.00)*
11	disadvantage				
12	Normal weight				
13		1342	0.4 (0.36-0.44)	-0.07 (-0.13-- 0.01)*	-0.07 (-0.13--0.01)*
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15	Overweight				
16		1375	0.31 (0.26-0.37)	-0.12 (-0.18-- 0.05)*	-0.11 (-0.18--0.04)*
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18	Obese	633	0.25 (0.14-0.36)	-0.13 (-0.26-0.01)*	-0.13 (-0.26-0.01)*
19					
20	English speaking				
21	country of birth	3129	0.34 (0.30-0.37)	-0.10 (-0.15-- 0.06)*	-0.1 (-0.15--0.05)*
22					
23	Non-English speaking	222	0.32 (0.18-0.46)	-0.15 (-0.32-0.02)	-0.14 (-0.32-0.04)
24	country of birth				
25	Never smokers				
26		2121	0.34 (0.29-0.38)	-0.10 (-0.15-- 0.04)*	-0.1 (-0.15--0.04)*
27					
28	Ex smokers				
29		894	0.27 (0.20-0.34)	-0.15 (-0.24-- 0.06)*	-0.15 (-0.24--0.06)*
30					
31	Current smokers	336	0.49 (0.36-0.63)	-0.01 (-0.20-0.19)	0.00 (-0.20-0.20)
32					
33	No chronic disease#				
34		1944	0.42 (0.37-0.47)	-0.10 (-0.16-- 0.04)*	-0.10 (-0.16--0.04)*
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	Sample size	Annualised WC change in Period 1	Model 1	Model 2	Model 3
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)*
<i>(B)</i>					
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)*

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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

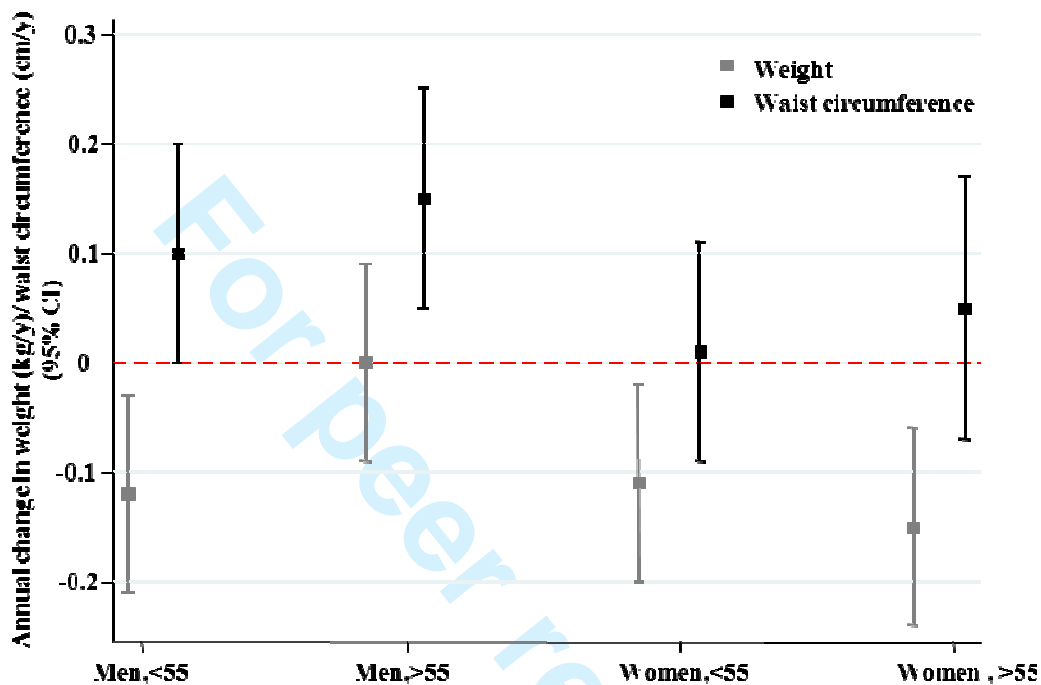
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

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.

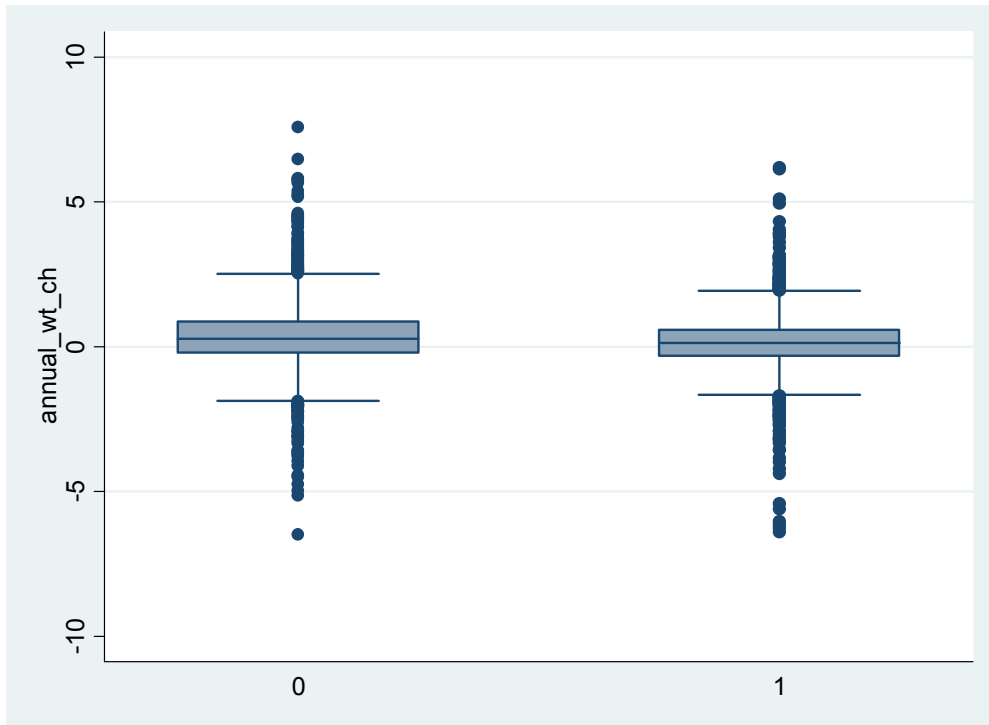


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Appendix

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

A. Annualised weight change



B. **Annualised** waist circumference change

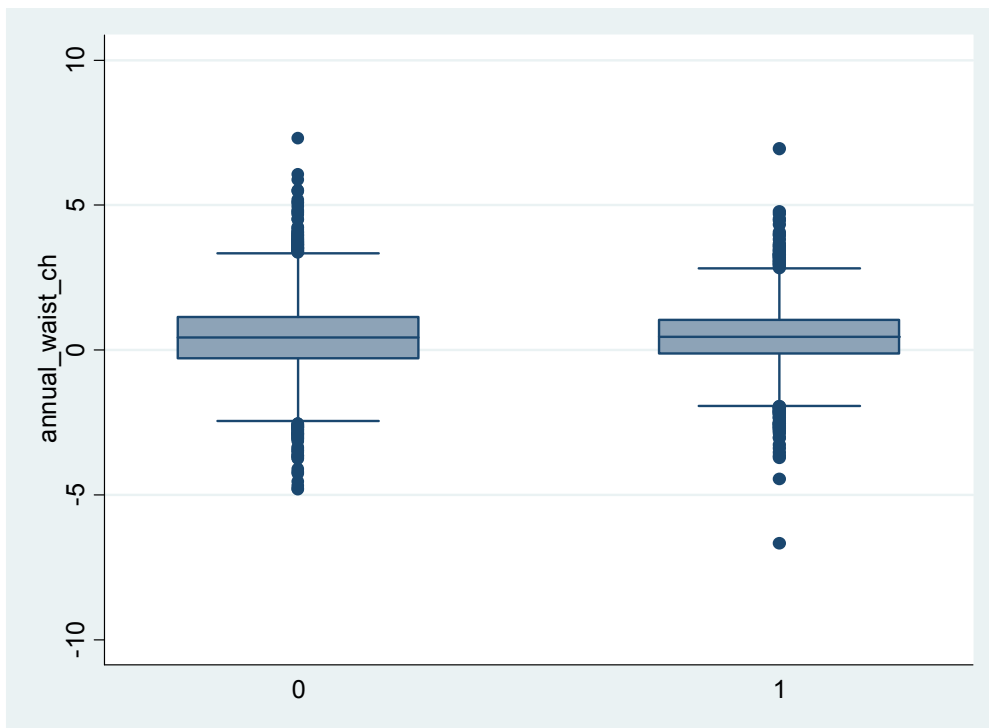


Table 1 Comparison of **annualised** weight and waist circumference change between Period 1 and Period 2 for matching age groups.

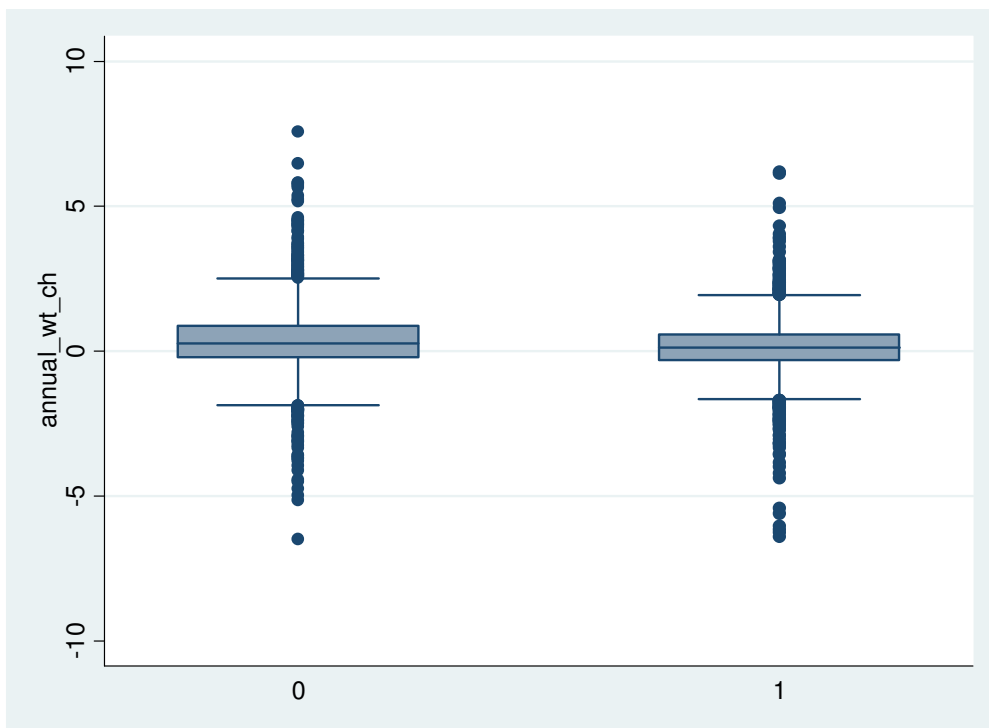
Sex	Age group	Difference in annualised weight change	Difference in annualised WC change
Men	25-34	-0.08 (-0.5, 0.35)	-0.10 (-0.53, 0.32)
	35-44	-0.18 (-0.34, -0.02)*	0.12 (-0.06, 0.30)
	45-54	-0.10 (-0.22, 0.01)	0.13 (0.01, 0.26)
	55-64	-0.03 (-0.1, 0.16)	0.20 (0.05, 0.34)
	65-74	-0.12 (-0.26, 0.02)	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)
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

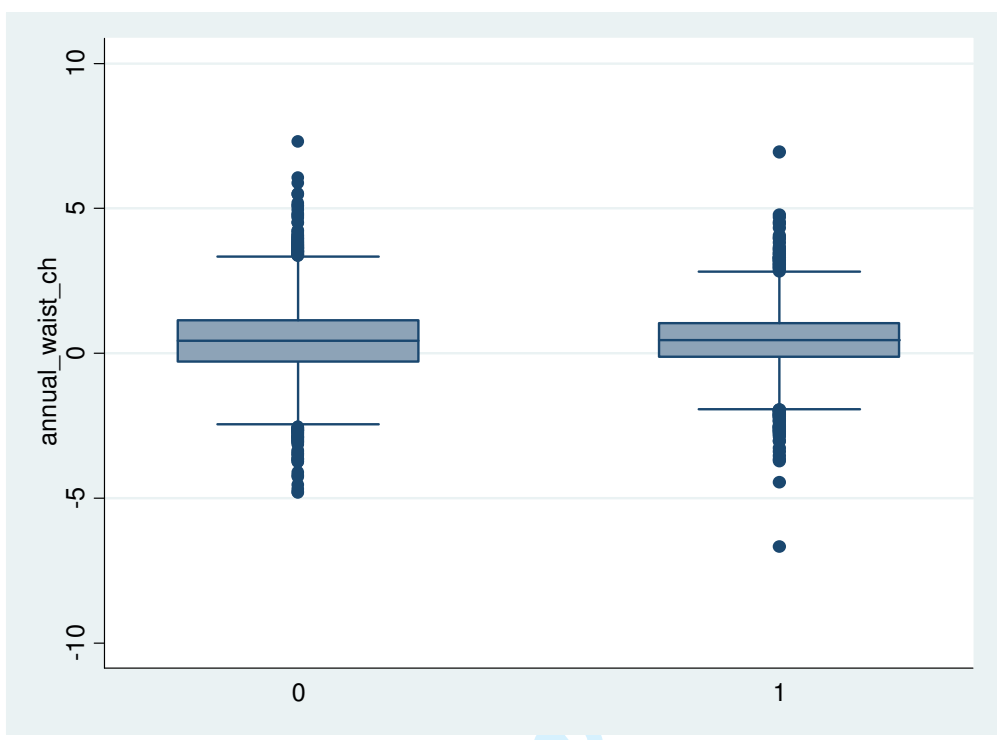
Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



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B. Annual waist circumference change



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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)
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.

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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>.

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

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Manuscripts

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2
3 **ABSTRACT**
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6 **Objective:** To assess in a single cohort whether annual weight and waist circumference (WC)
7
8 change has varied over time.
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11 **Design:** Longitudinal cohort study with three surveys, 1– 1999/2000; 2– 2004/2005; 3–
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13 2011/2012. Generalized linear mixed models with random effects were used to compare
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15 annualised weight and WC change between surveys 1 and 2 (Period 1) with that between
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17 surveys 2 and 3 (Period 2). Models were adjusted for age to analyse changes with time rather
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19 than age. Models were additionally adjusted for sex, education status, area-level socio-
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21 economic disadvantage, ethnicity, body mass index, diabetes status, and smoking status.
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25 **Setting:** The Australian Diabetes, Obesity and Lifestyle study (AusDiab)- a population-
26
27 based, stratified-cluster survey of 11,247 adults aged ≥ 25 years.
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31 **Participants:** 3,351 Australian adults who attended each of three surveys and had complete
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33 measures of weight, WC and covariates.
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37 **Primary outcome measures:** Weight and WC were measured at each survey. Change in
38
39 weight and WC was annualised for comparison between the two Periods.
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41
42 **Results:** Mean weight and WC increased in both Periods (0.34kg/y, 0.43cm/y Period 1;
43
44 0.13kg/y, 0.46 cm/y Period 2). Annualised weight gain in Period 2 was 0.11kg/year (95% CI
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46 0.06–0.15) less than Period 1. Lesser annual weight gain between the two periods was not
47
48 seen for those with greatest area-level socio-economic disadvantage, or in men over the age
49
50 of 55. In contrast, the annualised WC increase in Period 2 was greater than Period 1
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52 (0.07cm/year, 95% CI 0.01–0.12). The increase was greatest in males 55+ and those with
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54 greater area-level socio-economic disadvantage.
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3 42 **Conclusions:** Between 2004/5–2011/2, Australian adults in a national study continued to gain
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5 43 weight, but more slowly than 1999/2000–2004/5. While weight gain may be slowing, this
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7 44 was not observed for older men or those in more disadvantaged groups, and the same cannot
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9 45 be said for WC.

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12 46 *Article summary*

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15 47 *Article focus*

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19 48 • We aimed to assess in a single cohort whether change in weight and waist
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21 49 circumference has changed in recent time periods, independent of age.

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24 50 *Key messages*

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27 51 • Between 2004/5–2011/2, Australian adults in this national cohort study continued to
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29 52 gain weight, but more slowly than 1999/2000–2004/5.
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32 53 • In contrast waist circumference gain was greater in the most recent period. Important
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34 54 differences were observed according to area-level socio-economic disadvantage.
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37 55 • While weight gain may be slowing, this has not been observed for older men or those
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39 56 in more disadvantaged groups.

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43 57 *Strengths and limitations*

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46 58 • Reliably measured data in a single nationally representative cohort in recent time
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48 59 periods
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51 60 • Analyses adjusted and matched for age for comparison between Periods to enable
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53 61 analysis of changes over time, rather than age
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3 62 • Selection and response bias may limit the generalisability of the results to the broader
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5 63 Australian population
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- Selection and response bias may limit the generalisability of the results to the broader Australian population

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3 65 Obesity in adults has increased rapidly over the past few decades, leading to prevalence of
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5 66 over one quarter in many developed countries [1]. There is growing acceptance that strong
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7 67 preventive measures are required to stem the increasing prevalence, with a variety of
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10 68 approaches implemented, ranging from social marketing through whole of community
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12 69 interventions to regulatory strategies.

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15 70 There have been some suggestions that obesity prevention interventions in children have had
16
17 71 a positive effect, due to the observation that the prevalence of obesity is no longer increasing
18
19 72 at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity
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21 73 prevalence at two time points since 1999 [4] concluded that in more developed nations a
22
23 74 likely slowing of the rate of increase in obesity prevalence was occurring in children, with a
24
25 75 possible turning point around 2000. However, trends in adults in this review generally
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27 76 appeared to be continuing to increase. Since this review, an analysis of US adults through the
28
29 77 repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and
30
31 78 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that
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33 79 time period in non-Hispanic white and Hispanic women, but continued increases in men and
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35 80 non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data
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37 81 suggests a continued increase in obesity prevalence in adults to 2012 [6]. However,
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39 82 prevalence data is driven by a range of factors, including migration, mortality and response
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41 83 bias. To determine whether the degree of weight gain in the population has slowed over time,
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43 84 a comparison of the rates of weight change is required.

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49 85 We aimed to analyse whether the degree of change in weight and waist circumference (WC)
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51 86 over time differed in a single cohort of adults, comparing weight and WC change in the same
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53 87 individuals between two consecutive time periods, adjusting for age. We used the national
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55 88 Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared annualised
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57 89 change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

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3 90 **METHODS**
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6 91 **Setting and Participants**
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9 92 The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based,
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11 93 stratified-cluster survey of 11, 247 adults aged ≥ 25 years, recruited in 1999 -2000
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13 94 (AusDiab1). Methods and response rates have been described previously[7]. Five-year
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15 95 follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted
16
17 96 in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical
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19 97 examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3,
20
21 98 respectively. For this analysis we excluded participants with missing data on weight or WC
22
23 99 at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those
24
25 100 participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a
26
27 101 final sample size of 3,351. Ethics approval was obtained from the International Diabetes
28
29 102 Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented
30
31 103 to participate in the study.
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36 104 All study assessments followed a similar protocol [8] [7]. Data were collected by
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38 105 interviewer-administered questionnaires on medical history, lifestyle and health behaviour.
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42 106 **Outcomes**
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45 107 Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm.
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47 108 Weight was measured without shoes, excess clothing, and items in pockets by a single
48
49 109 measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam
50
51 110 balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was
52
53 111 recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior
54
55 112 to each set of measurements. BMI was obtained from the calculation of weight (kg) divided
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3 113 by height (m²). Annual weight change was calculated as the difference in weight between
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5 114 AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time
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7 115 between the two consecutive surveys.
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9
10 116 Waist circumference was measured twice, halfway between the lower border of the ribs and
11
12 117 the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the
13
14 118 mean of the two closest measurements was calculated. Annualised WC change was
15
16 119 calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by
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18 120 the follow-up time between the two consecutive surveys.
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22 121 **Co-factors**

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25 122 Data on education, country of birth, smoking and physical activity and television
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27 123 viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was
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29 124 ascertained by asking if participants had been told by a doctor or nurse that they had angina,
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31 125 myocardial infarction, or stroke.
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35 126 Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than
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37 127 daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked
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39 128 tobacco daily) combined [9] [7].
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42 129 Education level was ascertained by asking the question “Which of these describes the highest
43
44 130 qualification you have received?” Education was categorised as secondary only (comprising
45
46 131 those with a secondary school qualification), diploma (comprising nursing or teaching
47
48 132 qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor
49
50 133 degree, post-graduate diploma or masters degree/doctorate)[10].
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54 134 Area-level socio-economic disadvantage was estimated using the Index of Relative
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56 135 Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was
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3 136 developed by the Australian Bureau of Statistics, to create a summary measure from a group
4
5 137 of 20 variables (related to education, income, employment, family composition, housing
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7 138 benefits, car ownership, ethnicity, English language proficiency, residential overcrowding)
8
9
10 139 displaying dimensions of social disadvantage [11]. The index is constructed so that high
11
12 140 values reflect areas with high socio-economic status (relative advantage) and low values
13
14 141 reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage
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16 142 were calculated amongst the final study sample.

17
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19 143 Physical activity was measured via an interviewer-administered Active Australia
20
21 144 questionnaire, which considered participation in predominantly leisure-time physical
22
23 145 activities (including walking for transport) during the previous week [12]. Total physical
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25 146 activity time was calculated as the sum of the time spent walking (if continuous and for ≥ 10
26
27 147 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-
28
29 148 intensity physical activity [13].

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33 149 Self-reported television viewing time was calculated as the total time spent watching
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35 150 television or videos in the previous week, and is considered a reliable and valid estimate of
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37 151 television viewing time among adults [14].

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41 152 Average daily energy intake was assessed using a self-administered food frequency
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43 153 questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with
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45 154 additional questions on food habits, portion size and consumption of alcoholic beverages. In
46
47 155 AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the
48
49 156 state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential
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51 157 measurement error, manual blood pressure measurements were adjusted as previously
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53 158 described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.
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3 159 Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus
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5 160 Optical, Tokyo, Japan) at a central laboratory [17].
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8 161 Classification of diabetes status has been described elsewhere [17]. Briefly, participants were
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10 162 classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and
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12 163 were either taking hypoglycaemic medication or had fasting plasma glucose (FPG)
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14 164 ≥ 7.0 mmol/L or a 2-hour plasma glucose (PG) ≥ 11.1 mmol/L. Participants not reporting
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16 165 diabetes but with FPG ≥ 7.0 mmol/L or 2-hour PG ≥ 11.1 mmol/L were classified as having
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18 166 'newly diagnosed diabetes'.
19

20 21 167 **Statistical analysis**

22
23 168 Baseline characteristics (means and proportions at AusDiab1) were compared between
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25 169 AusDiab participants with and without complete measures at AusDiab 1, 2 and 3.
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27 170 Characteristics of the included population were also compared in 2000 and 2005,
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29 171 representing the two baseline surveys for the two weight change periods.
30
31 172 The difference in annualised weight and WC change in Period 1 (2000 to 2005), compared to
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33 173 Period 2 (2005 and 2012), was assessed using linear regression analysis. Generalized linear
34
35 174 mixed models with random effects were used to analyse the association between study period
36
37 175 on annual weight or WC change. This model includes random effects associated with both
38
39 176 the cluster and the units of analysis (participants) to take the clustered structure of the data
40
41 177 into account and to allow the residuals associated with the longitudinal measures on the same
42
43 178 unit of analysis to be correlated. Models were adjusted sequentially for age and sex, (Model
44
45 179 1), additionally adjusting for smoking, education, area level disadvantage and country of birth
46
47 180 (Model 2), additionally adjusting for baseline BMI and diabetes status (Model 3), and
48
49 181 additionally adjusting for baseline TV time, exercise time, and energy intake (Model 4).
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51 182 Baseline refers to the variables measured at AusDiab1 for change in Period 1, and AusDiab2
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53 183 for change in Period 2. Adjustment for age enables the differences in weight and WC change
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3 184 observed between the two Periods to be attributed to time rather than age. The association
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5 185 between study period and annualised weight and WC change was also analysed across sub-
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7 186 groups and interaction terms between study period with age or sex were analysed.

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10 187 The primary analyses were repeated after excluding the few participants with annual weight
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12 188 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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14 189 age group of 30–80.

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16 190 All analyses were performed in STATA (version 11.0), with statistical significance set at the
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18 191 5% level.

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3 193 **RESULTS**
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6 194 The population with complete measures was similar to the total AusDiab cohort with respect
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8 195 to sex and weight, but was younger, with higher educational attainment, and a higher
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10 196 prevalence of never smoking (Table 1). The population with complete measures also had a
11
12 197 lower prevalence of chronic disease. There was no appreciable difference between the two
13
14 198 groups for weight change in Period 1 after adjustment for differences in age and sex.

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18 199 (Table 1 here)
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20 200 Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to
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22 201 being five years older, the population had a higher prevalence of diabetes (predominantly
23
24 202 type 2). In both periods the average change in weight and WC was a gain. In Period 2, a
25
26 203 smaller proportion of the population gained weight and annualised weight gain was less, at
27
28 204 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser
29
30 205 weight change across the entire distribution of weight change in Period 2, with minimal
31
32 206 difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile
33
34 207 of weight change (Appendix Figure 1A). For WC, there was no difference in the crude
35
36 208 annualised change between the two periods (Table 2). In contrast to weight change, this
37
38 209 resulted from both a smaller gain in those whose WC increased and a smaller loss in those
39
40 210 whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change
41
42 211 was 0.69 (0.68 in Period 1, and 0.71 in Period 2).
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48 212 (Table 2 here)
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51 213 Comparison of the crude annualised weight change for matching 10-year age-groups in
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53 214 Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups,
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55 215 although these differences were only significant for men aged 35–44, and women 45–54 and
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3 216 65–74 (Table 3). Comparison of the crude annualised WC change for matching age-groups in
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5 217 Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a
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7 218 generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64;
8
9 219 Table 3).

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12 220 (Table 3 here)

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15 221 The difference in annualised weight and WC change in Period 2, compared to Period 1, was
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17 222 assessed using linear regression analysis (Table 4). In Period 2, annualised weight gain was
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19 223 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after
20
21 224 further adjustment for smoking status, education status, ethnicity, area-level socio-economic
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23 225 disadvantage, baseline BMI and diabetes status (Table 4A), nor after adjustment for TV time,
24
25 226 exercise time and energy intake (results not shown).

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29 227 Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 4A),
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31 228 with suggestions of a greater difference over time in women, and those aged under 55 years
32
33 229 (although no interaction tests on these factors were significant). Annualised weight gain in
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35 230 Period 2 was non-significantly less than in Period 1 for those with high educational
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37 231 attainment (borderline significant), obesity, and those from a non-English speaking
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39 232 background. No difference in annualised weight gain between the two periods was observed
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41 233 for those in the tertile of greatest area-level socio-economic disadvantage, nor for current
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43 234 smokers.

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48 235 In Period 2, annualised WC gain was 0.07 cm/year more than in Period 1 (Table 4B). This
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50 236 did not alter substantially after further adjustment for smoking status, education status, area-
51
52 237 level socio-economic disadvantage, ethnicity, baseline BMI and diabetes status (Table 4B),
53
54 238 nor after adjustment for TV time, exercise time and energy intake (results not shown).

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3 239 In stratified analyses no difference in annualised WC gain between the two periods was
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5 240 observed for women, those aged <55 years, those in the highest education group, those with
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7 241 normal weight nor ex-smokers. Annualised WC gain was less in Period 2 than Period 1 for
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9 242 those in the tertile of least area-level socio-economic disadvantage (-0.14cm/year 95%CI -
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11 243 .05, -0.23).

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15 244 (Table 4 here)

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18 245 For both weight and WC, there was an apparent combined sex and age effect, such that older
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20 246 men had the least favourable changes over time (Figure 1).

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23 247 The primary analyses were repeated after excluding the few participants with annual weight
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25 248 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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27 249 age group of 30–80. No differences in results were seen.

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35 36 252 **DISCUSSION**

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39 253 In this analysis of a single cohort of Australian adults, weight and WC increased in the most
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41 254 recent period in all population sub-groups examined. Age-adjusted annualised weight gain
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43 255 between 2005–2012 was less than between 1999/2000–2005, but annualised WC gain was
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45 256 greater. Lesser weight gain over time was not seen in older men or those with greatest area-
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47 257 level socio-economic disadvantage.

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55 259 The lack of difference in weight and WC change between the two periods observed for
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57 260 current smokers, those from a non-English speaking background and those with obesity, is

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3 261 likely to reflect small sample sizes in these groups. In general, adjustment for covariates had
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5 262 little effect on the observed associations between study period and weight and WC change.
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7 263 As time spent watching TV, exercise and energy intake might be expected to be mediating
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9 264 much of the observed changes, we had expected an observable reduction in the difference
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11 265 between study periods after adjustment for these factors. The lack of impact after adjustment
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13 266 likely reflects that they are relatively blunt instruments to detect small changes in behaviour
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16 267 over time. The self-reported nature of these behavioural questionnaires is associated with
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18 268 both differential and non-differential error [18] [19]. While validated, the FFQ is has a
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20 269 limited list of foods and is affected by the inability of individuals to accurately report their
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23 270 food intake retrospectively over a long period of time [20]. Further the Active Australia
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25 271 questionnaire only refers to leisure time activity and TV watching is only one component of
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27 272 sitting time.
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30 273
31 274 The general observation that weight gain may be lessening over time supports the cross-
32
33 275 sectional time series observations of a plateau in the prevalence of obesity and rate of change
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35 276 in BMI [4]. However, these results also suggest that the general observations do not tell the
36
37 277 whole story, with large differences between different population subgroups, and a contrasting
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39 278 observation for waist circumference. The sex differences observed here are similar to the
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41 279 cross-sectional trends reported for American adults for whom a clear plateau in obesity
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43 280 prevalence has been observed for women but not men [5]. The differences we observed
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45 281 according to level of area-level socio-economic disadvantage also reflect findings from the
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47 282 review of obesity trends in which the levelling off of obesity was generally more pronounced
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49 283 in groups with higher socio-economic position [4]. It will be important to do a similar
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51 284 analysis in a longitudinal children's cohort, as their experience is likely to differ from that of
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53 285 adults. Children have been exposed to a wide range of obesity prevention interventions,
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3 286 particularly in schools, in countries such as Australia and cross-sectional trends clearly
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5 287 suggest a plateauing in the prevalence of obesity in children [4].
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8 288 The observation that rates of WC change may be continuing to increase even as rates of
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10 289 weight change decrease may reflect prior findings using the NHANES data that WC is
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12 290 increasing to a greater extent than expected from changes in weight [21] [22]. While we
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14 291 observed changes in weight and WC to be highly correlated these results combined suggest a
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16 292 preferential increase in abdominal adiposity over time, which is thought to be associated with
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18 293 greater risk of cardio-metabolic outcomes [23]. The potential implication that current
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20 294 bodyweight trends are leading a more metabolically active obesity, with increased risks for
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22 295 outcomes such as diabetes, hypertension and cardiovascular disease warrants further
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24 296 investigation.
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29 297 The key strength of the current study is that for the first time it addresses this important
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31 298 question through an analysis of the same cohort of adults over two distinct but recent time
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33 299 periods, independent of the effects of ageing. In doing this, conclusions can be drawn about
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35 300 the changes over time independent of unmeasurable differences in cohorts. Other strengths
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37 301 include the national population sampling strategy of the AusDiab cohort and the measured
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39 302 weight and WC at each study wave.
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43 303 The potential limitation of the current study is the lack of generalisability of the included
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45 304 cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who
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47 305 attended all three waves are more select again, with higher educational attainment and a
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49 306 lower prevalence of chronic disease and risk factors. It is possible that a generally more
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51 307 healthy and health conscious population has a stronger response to population health
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53 308 messages, and consequently the lesser weight gain observed here in consecutive age cohorts
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55 309 over time may be greater than would be observed for the general population. However, the
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3 310 current observations lend support to the concept that weight gain is decreasing over time in
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5 311 the population, even if the AusDiab cohort represents a particularly sensitive indicator. One
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7 312 further potential limitation is the use of different weighing scales at AusDiab 2 and 3
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10 313 compared to AusDiab1. Although all scales were calibrated in the same way at each survey
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12 314 wave, differences in variability between the scales may have led to more variability in the
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14 315 change in weight in Period 1 than Period 2.

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17 316 The results also suggest there is no room for complacency in obesity prevention. The rates of
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19 317 overweight and obesity remain high, the average change in weight and WC remains an
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21 318 increase and there is no reduction in the rate of WC gain. Further, no decrease in the rate of
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23 319 weight or WC change were observed in older men. Finally, the observation that no decrease
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25 320 in rates of weight and WC change is being seen by those living in the most socially
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27 321 disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the
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29 322 social inequalities in obesity, and consequent ill health [24]. It is critical that further studies
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31 323 are conducted to confirm these findings and that we work to identify the causes of the
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33 324 observed changes, including the differences observed in specific population sub-groups.
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38 325 In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a
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40 326 faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While weight
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42 327 gain may be slowing, it does not appear to be affecting older men or those in more
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44 328 disadvantaged groups, and the same cannot be said for WC.
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8

9
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12 337 Extra data is available by emailing A Peeters at anna.peeters@bakeridi.edu.au
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16 338 ***Authorship statement***
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18 339 AP conceived of the article, executed the analysis and writing of the article and is guarantor
19

20 340 for the article. JS, DM and KB contributed to the ideas included within and writing of the
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22 341 article, and provision of data. PZ contributed to the writing of the article and provision of
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23 365 None
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366 **References**

- 367 1. International Association for the Study of Obesity. Obesity the global epidemic. Secondary
368 Obesity the global epidemic 2013.
369 <http://www.iaso.org/iotf/obesity/obesitytheglobalepidemic/>.
- 370 2. Stamatakis E, Zaninotto P, Falaschetti E, et al. Time trends in childhood and adolescent
371 obesity in England from 1995 to 2007 and projections of prevalence to 2015. *J*
372 *Epidemiol Community Health* 2010;**64**(2):167-74 doi:
373 10.1136/jech.2009.098723[published Online First: Epub Date].
- 374 3. Sundblom E, Petzold M, Rasmussen F, et al. Childhood overweight and obesity
375 prevalences levelling off in Stockholm but socioeconomic differences persist. *Int J*
376 *Obes (Lond)* 2008;**32**(10):1525-30 doi: 10.1038/ijo.2008.104[published Online First:
377 Epub Date].
- 378 4. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the
379 year 1999--a review of evidence and perspectives. *Obes Rev* 2010;**11**(12):835-46 doi:
380 10.1111/j.1467-789X.2010.00810.x[published Online First: Epub Date].
- 381 5. Flegal KM, Carroll MD, Kit BK, et al. Prevalence of obesity and trends in the distribution
382 of body mass index among US adults, 1999-2010. *JAMA* 2012;**307**(5):491-7 doi:
383 10.1001/jama.2012.39[published Online First: Epub Date].
- 384 6. Statistics ABo. Australian Health Survey: First Results, 2011-12. Canberra: Australian
385 Bureau of Statistics, 2012.
- 386 7. Dunstan DW, Zimmet PZ, Welborn TA, et al. The Australian Diabetes, Obesity and
387 Lifestyle Study (AusDiab)--methods and response rates. *Diabetes Res Clin Pract*
388 2002;**57**(2):119-29
- 389 8. Cameron AJ, Welborn TA, Zimmet PZ, et al. Overweight and obesity in Australia: the
390 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Med J Aust*
391 2003;**178**(9):427-32
- 392 9. Risk Factor Prevalence Management Committee. Risk factor prevalence study No.3, 1989:
393 National Heart Foundation and Australian Institute of Health, 1990.
- 394 10. Williams ED, Magliano DJ, Zimmet PZ, et al. Area-level socioeconomic status and
395 incidence of abnormal glucose metabolism: the Australian Diabetes, Obesity and
396 Lifestyle (AusDiab) study. *Diabetes Care* 2012;**35**(7):1455-61 doi: 10.2337/dc11-
397 1410[published Online First: Epub Date].

- 1
2
3 398 11. Statistics ABo. Information Paper - Census of Population and Housing: Socio-Economic
4 399 Indexes for Areas Australia 2001. : Australian Bureau of Statistics, 2001.
- 5
6 400 12. Australian Institute of Health and Welfare. The Active Australia Survey. A guide and
7 401 manual for implementation, analysis and reporting. Canberra: Australian Institute of
8 402 Health and Welfare, 2003.
- 9
10 403 13. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results
11 404 of the 1999 National Physical Sctivity Survey. Australian Institute of Health and
12 405 Welfare cat No CVD10. Canberra: Australian Institute of Health and Welfare, 2000.
- 13
14 406 14. Salmon J, Bauman A, Crawford D, et al. The association between television viewing and
15 407 overweight among Australian adults participating in varying levels of leisure-time
16 408 physical activity. *Int. J. Obes. Relat. Metab. Disord.* 2000;**24**:600-6
- 17
18 409 15. Ireland P, Jolley D, Giles G, et al. Development of the Melbourne FFQ: A food frequency
19 410 questionnaire for use in an Australian prospective study involving an ethnically
20 411 diverse cohort. *Asia Pacific J Clin Nutr* 1994;**3**:19-31
- 21
22 412 16. Briganti EM, Shaw JE, Chadban SJ, et al. Untreated hypertension among Australian
23 413 adults: the 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab).
24 414 *Med J Aust* 2003;**179**(3):135-9
- 25
26 415 17. Magliano DJ, Barr EL, Zimmet PZ, et al. Glucose indices, health behaviors, and
27 416 incidence of diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle
28 417 Study. *Diabetes Care* 2008;**31**(2):267-72 doi: 10.2337/dc07-0912[published Online
29 418 First: Epub Date]].
- 30
31 419 18. Hebert JR, Hurley TG, Peterson KE, et al. Social desirability trait influences on self-
32 420 reported dietary measures among diverse participants in a multicenter multiple risk
33 421 factor trial. *J Nutr* 2008;**138**(1):226S-34S
- 34
35 422 19. Booth ML, Owen N, Bauman AE, et al. Retest reliability of recall measures of leisure-
36 423 time physical activity in Australian adults. *Int J Epidemiol* 1996;**25**(1):153-9
- 37
38 424 20. Dodd KW, Guenther PM, Freedman LS, et al. Statistical methods for estimating usual
39 425 intake of nutrients and foods: a review of the theory. *J Am Diet Assoc*
40 426 2006;**106**(10):1640-50 doi: 10.1016/j.jada.2006.07.011[published Online First: Epub
41 427 Date]].
- 42
43 428 21. Elobeid MA, Desmond RA, Thomas O, et al. Waist circumference values are increasing
44 429 beyond those expected from BMI increases. *Obesity (Silver Spring)*
45 430 2007;**15**(10):2380-3 doi: 15/10/2380 [pii]10.1038/oby.2007.282[published Online
46 431 First: Epub Date]].

- 1
2
3 432 22. Walls HL, Stevenson CE, Mannan HR, et al. Comparing trends in BMI and waist
4 433 circumference. *Obesity (Silver Spring)* 2011;**19**(1):216-9 doi: oby2010149 [pii
5 434 10.1038/oby.2010.149[published Online First: Epub Date]].
6
7
8
9 435 23. Welborn TA, Dhaliwal SS, Bennett SA. Waist-hip ratio is the dominant risk factor
10 436 predicting cardiovascular death in Australia. *Med J Aust* 2003;**179**(11-12):580-5
11
12 437 24. Backholer K, Mannan HR, Magliano D, et al. Projected socioeconomic disparities in the
13 438 prevalence of obesity amongst Australian adults. *Australian and New Zealand Journal*
14 439 *of Public Health* 2012;**in press**
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5 443 **Figures**

6
7 444 Figure 1. Difference in annualised change in weight (kg/year) or waist circumference

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9 445 (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.

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451 **Tables**

452 **Table 1** Comparison of characteristics in 1999/2000 between the included and excluded
 453 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

454 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)*

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5	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)
6						
7	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)
8						
9	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)*
10						
11	Education- secondary & trade					
12	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)*
13						
14	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)
15						
16						
17	Area level disadvantage- tertile	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)*
18	of most disadvantage					
19	Area level disadvantage-	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)*
20	middle tertile					
21	Area level disadvantage- tertile					
22	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)*
23						
24	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)
25						
26	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)
27						
28	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)
29						
30						
31	English speaking country of					
32	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)*
33						
34	Non-English speaking country					
35	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)
36						
37	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)*
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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

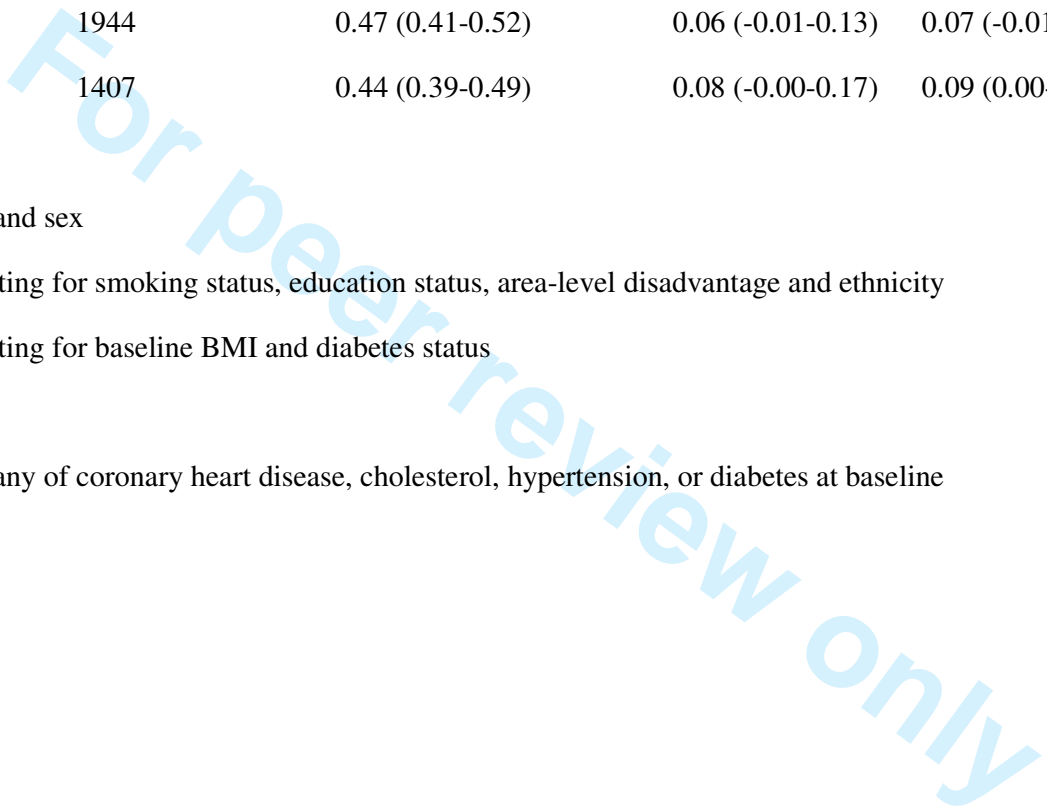
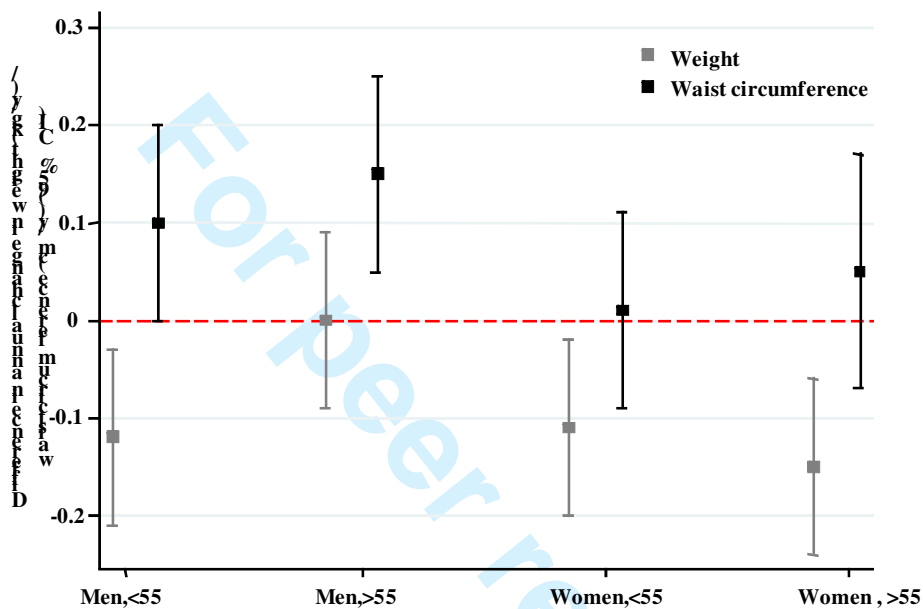


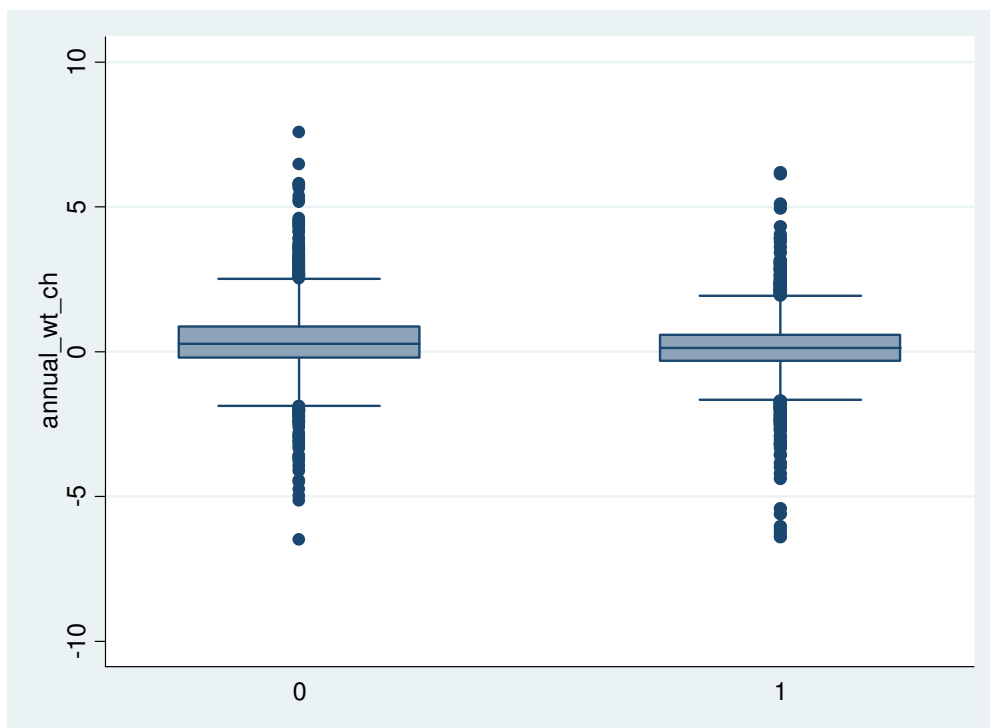
Figure 1. Difference in annualised change in weight (kg/year) or waist circumference (cm/year) between Period 2 and Period 1, by age and sex. Adjusted for age.



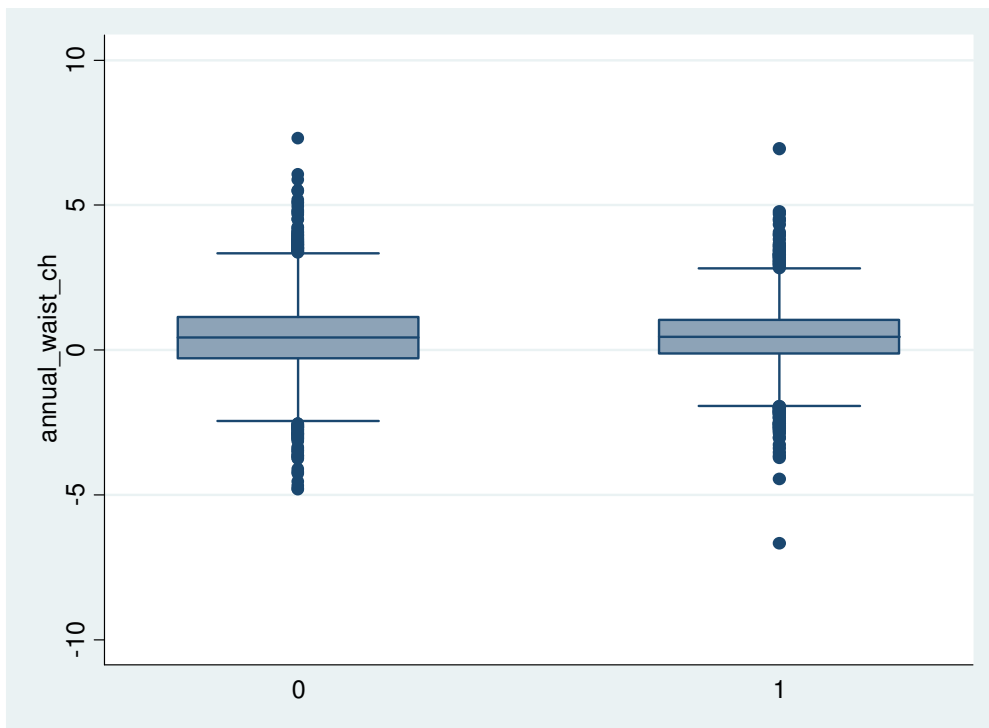
Appendix

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

A. Annualised weight change



B. Annualised waist circumference change



Review only

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3 1 Changes in the rates of weight and waist circumference gain in Australian adults over time.
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7

8 Running title: Change in weight and waist gain over time

9

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3 20 *Data sharing*
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6 21 Extra data is available by emailing A Peeters at anna.peeters@bakeridi.edu.au
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12 23 *Authorship statement*
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15 24 AP conceived of the article, executed the analysis and writing of the article and is guarantor
16
17 25 for the article. JS, DM and KB contributed to the ideas included within and writing of the
18
19 26 article, and provision of data. PZ contributed to the writing of the article and provision of
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21 27 data.
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32
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34
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36
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38

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48
49 39 Diabetes Service-Canberra, Department of Health and Community Services - Northern
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51 40 Territory, Department of Health and Human Services – Tasmania, Department of Health –
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53 41 New South Wales, Department of Health – Western Australia, Department of Health – South
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55 42 Australia, Department of Human Services – Victoria, Diabetes Australia, Diabetes Australia
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43 Northern Territory, Eli Lilly Australia, Estate of the Late Edward Wilson, GlaxoSmithKline,
44 Jack Brockhoff Foundation, Janssen-Cilag, Kidney Health Australia, Marian & FH Flack
45 Trust, Menzies Research Institute, Merck Sharp & Dohme, Novartis Pharmaceuticals, Novo
46 Nordisk Pharmaceuticals, Pfizer Pty Ltd, Pratt Foundation, Queensland Health, Roche
47 Diagnostics Australia, Royal Prince Alfred Hospital, Sydney, Sanofi Aventis, Sanofi
48 Synthelabo.

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3 49 *Article summary*
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6 50 *Article focus*
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- 9 • We aimed to assess in a single cohort whether change in weight and waist
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11 circumference has changed in recent time periods, independent of age.
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14 53 *Key messages*
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17 • Between 2004/5–2011/2, Australian adults in this national cohort study continued to
18
19 gain weight, but more slowly than 1999/2000–2004/5.
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- 22
23 • In contrast waist circumference gain was greater in the most recent period. Important
24
25 differences were observed according to area-level socio-economic disadvantage.
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- 28 • While weight gain may be slowing, this has not been observed for older men or those
29
30 in more disadvantaged groups.
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33 60 *Strengths and limitations*
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- 36 • Reliably measured data in a single nationally representative cohort in recent time
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38 periods
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- 41 • Analyses adjusted and matched for age for comparison between Periods to enable
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43 analysis of changes over time, rather than age
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- 46 • Selection and response bias may limit the generalisability of the results to the broader
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48 Australian population
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68 **ABSTRACT**

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

71 **Design:** Longitudinal cohort study with three surveys, 1– 1999/2000; 2– 2004/2005; 3–
72 2011/2012. Generalized linear mixed models with random effects were used to compare
73 annualised weight and WC change between surveys 1 and 2 (Period 1) with that between
74 surveys 2 and 3 (Period 2). Models were adjusted for age to analyse changes with time rather
75 than age. Models were additionally adjusted for sex, education status, area-level socio-
76 economic disadvantage, ethnicity, body mass index, diabetes status, and smoking status.

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

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

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

83 **Results:** Mean weight and WC increased in both Periods (0.34kg/y, 0.43cm/y Period 1;
84 0.13kg/y, 0.46 cm/y Period 2). Annualised weight gain in Period 2 was 0.11kg/year (95% CI
85 0.06–0.15) less than Period 1. Lesser annual weight gain between the two periods was not
86 seen for those with greatest area-level socio-economic disadvantage, or in men over the age
87 of 55. In contrast, the annualised WC increase in Period 2 was greater than Period 1
88 (0.07cm/year, 95% CI 0.01–0.12). The increase was greatest in males 55+ and those with
89 greater area-level socio-economic disadvantage.

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3 90 **Conclusions:** Between 2004/5–2011/2, Australian adults in a national study continued to gain
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5 91 weight, but more slowly than 1999/2000–2004/5. While weight gain may be slowing, this
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7 92 was not observed for older men or those in more disadvantaged groups, and the same cannot
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9 93 be said for WC.
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3 95 Obesity in adults has increased rapidly over the past few decades, leading to prevalence of
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5 96 over one quarter in many developed countries [1]. There is growing acceptance that strong
6
7 97 preventive measures are required to stem the increasing prevalence, with a variety of
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10 98 approaches implemented, ranging from social marketing through whole of community
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12 99 interventions to regulatory strategies.

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15 100 There have been some suggestions that obesity prevention interventions in children have had
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17 101 a positive effect, due to the observation that the prevalence of obesity is no longer increasing
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19 102 at the same rate [2] [3]. A recent review of 52 studies, from 25 countries, comparing obesity
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21 103 prevalence at two time points since 1999 [4] concluded that in more developed nations a
22
23 104 likely slowing of the rate of increase in obesity prevalence was occurring in children, with a
24
25 105 possible turning point around 2000. However, trends in adults in this review generally
26
27 106 appeared to be continuing to increase. Since this review, an analysis of US adults through the
28
29 107 repeated National Health and Nutrition Examination Surveys (NHANES) between 1999 and
30
31 108 2010 suggested no increase in mean body mass index (BMI) or obesity prevalence over that
32
33 109 time period in non-Hispanic white and Hispanic women, but continued increases in men and
34
35 110 non-Hispanic black and Mexican American women [5]. In Australia, the latest reported data
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37 111 suggests a continued increase in obesity prevalence in adults to 2012 [6]. However,
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39 112 prevalence data is driven by a range of factors, including migration, mortality and response
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41 113 bias. To determine whether the degree of weight gain in the population has slowed over time,
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43 114 a comparison of the rates of weight change is required.

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49 115 We aimed to analyse whether the degree of change in weight and waist circumference (WC)
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51 116 over time differed in a single cohort of adults, comparing weight and WC change in the same
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53 117 individuals between two consecutive time periods, adjusting for age. We used the national
54
55 118 Australian Diabetes, Obesity and Lifestyle cohort (AusDiab) [7], and compared annualised
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57 119 change in weight and WC between 2000 and 2005 to that between 2005 and 2012.

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3 120 **METHODS**
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6 121 **Setting and Participants**
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9 122 The Australian Diabetes, Obesity and Lifestyle study (AusDiab) is a population-based,
10
11 123 stratified-cluster survey of 11, 247 adults aged ≥ 25 years, recruited in 1999 -2000
12
13 124 (AusDiab1). Methods and response rates have been described previously[7]. Five-year
14
15 125 follow-up was conducted in 2004-2005 (AusDiab2) and a 12-year follow-up was conducted
16
17 126 in 2012 (AusDiab3). From the original cohort, 6,400 and 4,614 returned for physical
18
19 127 examination and interviewer-administered questionnaire at AusDiab2 and AusDiab3,
20
21 128 respectively. For this analysis we excluded participants with missing data on weight or WC
22
23 129 at any of AusDiab 1, 2 or 3, leaving 3,908 participants. We further excluded those
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25 130 participants missing any of the variables used as covariates at AusDiab 1 or 2, resulting in a
26
27 131 final sample size of 3,351. Ethics approval was obtained from the International Diabetes
28
29 132 Institute, Monash University, and the Alfred Hospital Melbourne. All participants consented
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31 133 to participate in the study.
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36 134 All study assessments followed a similar protocol [8] [7]. Data were collected by
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38 135 interviewer-administered questionnaires on medical history, lifestyle and health behaviour.
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41 136 **Outcomes**
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44 137 Height was measured without shoes, using a stadiometer and recorded to the nearest 0.5 cm.
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46 138 Weight was measured without shoes, excess clothing, and items in pockets by a single
47
48 139 measurement at each survey. Weight at AusDiab1 was measured using a mechanical beam
49
50 140 balance. Weight at AusDiab 2 and 3 was measured using digital weighing scales. Weight was
51
52 141 recorded to the nearest 0.1 kg. At all surveys, scales were calibrated using 5kg weights prior
53
54 142 to each set of measurements. BMI was obtained from the calculation of weight (kg) divided
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3 143 by height (m²). Annual weight change was calculated as the difference in weight between
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5 144 AusDiab 1 and 2 (Period 1), or AusDiab 2 and 3 (Period 2), divided by the follow-up time
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7 145 between the two consecutive surveys.
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10 146 Waist circumference was measured twice, halfway between the lower border of the ribs and
11
12 147 the iliac crest on a horizontal plane. If measurements varied by >2 cm, a third was taken; the
13
14 148 mean of the two closest measurements was calculated. Annualised WC change was
15
16
17 149 calculated as the difference in WC between AusDiab 1 and 2, or AusDiab 2 and 3, divided by
18
19 150 the follow-up time between the two consecutive surveys.
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22 151 **Co-factors**

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25 152 Data on education, country of birth, smoking and physical activity and television
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27 153 viewing habits were obtained by questionnaire. Self-reported cardiovascular disease was
28
29 154 ascertained by asking if participants had been told by a doctor or nurse that they had angina,
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31 155 myocardial infarction, or stroke.
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35 156 Smoking status was defined as 1) current daily smoker and 2) ex-smoker (smoking less than
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37 157 daily for at least the last 3 months, but used to smoke daily) and non-smoker (never smoked
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39 158 tobacco daily) combined [9] [7].
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42 159 Education level was ascertained by asking the question “Which of these describes the highest
43
44 160 qualification you have received?” Education was categorised as secondary only (comprising
45
46 161 those with a secondary school qualification), diploma (comprising nursing or teaching
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48 162 qualification, trade certificate or undergraduate diploma), and degree (comprising bachelor
49
50 163 degree, post-graduate diploma or masters degree/doctorate)[10].
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54 164 Area-level socio-economic disadvantage was estimated using the Index of Relative
55
56 165 Disadvantage code from the Socio-economic Indexes for Areas (SEIFA). The index was
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3 166 developed by the Australian Bureau of Statistics, to create a summary measure from a group
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5 167 of 20 variables (related to education, income, employment, family composition, housing
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7 168 benefits, car ownership, ethnicity, English language proficiency, residential overcrowding)
8
9
10 169 displaying dimensions of social disadvantage [11]. The index is constructed so that high
11
12 170 values reflect areas with high socio-economic status (relative advantage) and low values
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14 171 reflect areas with low socio-economic status (relative disadvantage). Tertiles of disadvantage
15
16 172 were calculated amongst the final study sample.

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19 173 Physical activity was measured via an interviewer-administered Active Australia
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21 174 questionnaire, which considered participation in predominantly leisure-time physical
22
23 175 activities (including walking for transport) during the previous week [12]. Total physical
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25 176 activity time was calculated as the sum of the time spent walking (if continuous and for ≥ 10
26
27 177 minutes) or performing moderate-intensity activity, plus double the time spent in vigorous-
28
29 178 intensity physical activity [13].

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33 179 Self-reported television viewing time was calculated as the total time spent watching
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35 180 television or videos in the previous week, and is considered a reliable and valid estimate of
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37 181 television viewing time among adults [14].

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41 182 Average daily energy intake was assessed using a self-administered food frequency
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43 183 questionnaire (FFQ) [15], which included 74 items (with 10 frequency options), with
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45 184 additional questions on food habits, portion size and consumption of alcoholic beverages. In
46
47 185 AusDiab1, blood pressure was measured using a standard mercury sphygmomanometer in the
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49 186 state of Victoria only and by Dinamap elsewhere. To account for any effect due to differential
50
51 187 measurement error, manual blood pressure measurements were adjusted as previously
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53 188 described [16]. In AusDiab 2 and 3, blood pressure was measured by an Omron machine.
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189 Fasting serum total cholesterol was measured with an Olympus AU600 analyser (Olympus
190 Optical, Tokyo, Japan) at a central laboratory [17].

191 Classification of diabetes status has been described elsewhere [17]. Briefly, participants were
192 classified as having 'known diabetes' if they reported having doctor diagnosed diabetes and
193 were either taking hypoglycaemic medication or had fasting plasma glucose (FPG)
194 ≥ 7.0 mmol/L or a 2-hour plasma glucose (PG) ≥ 11.1 mmol/L. Participants not reporting
195 diabetes but with FPG ≥ 7.0 mmol/L or 2-hour PG ≥ 11.1 mmol/L were classified as having
196 'newly diagnosed diabetes'.

197 **Statistical analysis**

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

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

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3 214 observed between the two Periods to be attributed to time rather than age. The association
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5 215 between study period and annualised weight and WC change was also analysed across sub-
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7 216 groups and interaction terms between study period with age or sex were analysed.

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10 217 The primary analyses were repeated after excluding the few participants with annual weight
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12 218 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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14 219 age group of 30–80.

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16 220 All analyses were performed in STATA (version 11.0), with statistical significance set at the
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3 223 **RESULTS**
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6 224 The population with complete measures was similar to the total AusDiab cohort with respect
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8 225 to sex and weight, but was younger, with higher educational attainment, and a higher
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10 226 prevalence of never smoking (Table 1). The population with complete measures also had a
11
12 227 lower prevalence of chronic disease. There was no appreciable difference between the two
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14 228 groups for weight change in Period 1 after adjustment for differences in age and sex.
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18 229 (Table 1 here)
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21 230 Participant characteristics in 2000 and 2005 were compared (Table 2). In 2005, in addition to
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23 231 being five years older, the population had a higher prevalence of diabetes (predominantly
24
25 232 type 2). In both periods the average change in weight and WC was a gain. In Period 2, a
26
27 233 smaller proportion of the population gained weight and annualised weight gain was less, at
28
29 234 0.13 kg/year compared to 0.34 kg/year in Period 1. This difference resulted from a lesser
30
31 235 weight change across the entire distribution of weight change in Period 2, with minimal
32
33 236 difference at the 5th percentile, increasing to a difference of 0.50kg/year at the 95th percentile
34
35 237 of weight change (Appendix Figure 1A). For WC, there was no difference in the crude
36
37 238 annualised change between the two periods (Table 2). In contrast to weight change, this
38
39 239 resulted from both a smaller gain in those whose WC increased and a smaller loss in those
40
41 240 whose WC decreased (Appendix Figure 1B). The correlation between weight and WC change
42
43 241 was 0.69 (0.68 in Period 1, and 0.71 in Period 2).
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48 242 (Table 2 here)
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51 243 Comparison of the crude annualised weight change for matching 10-year age-groups in
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53 244 Periods 1 and 2 indicated a smaller weight gain in Period 2 for most age and sex groups,
54
55 245 although these differences were only significant for men aged 35–44, and women 45–54 and
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3 246 65–74 (Table 3). Comparison of the crude annualised WC change for matching age-groups in
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5 247 Periods 1 and 2 indicated no difference in WC gain between the two periods for women and a
6
7 248 generally larger WC gain in Period 2 for men (significant for men aged 45–54 and 55–64;
8
9 249 Table 3).

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12 250 (Table 3 here)

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15 251 The difference in annualised weight and WC change in Period 2, compared to Period 1, was
16
17 252 assessed using linear regression analysis (Table 4). In Period 2, annualised weight gain was
18
19 253 0.11 kg/year (95% CI 0.06, 0.15) less than in Period 1. This did not alter substantially after
20
21 254 further adjustment for smoking status, education status, ethnicity, area-level socio-economic
22
23 255 disadvantage, baseline BMI and diabetes status (Table 4A), nor after adjustment for TV time,
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25 256 exercise time and energy intake (results not shown).

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29 257 Annualised weight gain in Period 2 was less than in Period 1 for most sub-groups (Table 4A),
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31 258 with suggestions of a greater difference over time in women, and those aged under 55 years
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33 259 (although no interaction tests on these factors were significant). Annualised weight gain in
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35 260 Period 2 was non-significantly less than in Period 1 for those with high educational
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37 261 attainment (borderline significant), obesity, and those from a non-English speaking
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39 262 background. No difference in annualised weight gain between the two periods was observed
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41 263 for those in the tertile of greatest area-level socio-economic disadvantage, nor for current
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43 264 smokers.

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48 265 In Period 2, annualised WC gain was 0.07 cm/year more than in Period 1 (Table 4B). This
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50 266 did not alter substantially after further adjustment for smoking status, education status, area-
51
52 267 level socio-economic disadvantage, ethnicity, baseline BMI and diabetes status (Table 4B),
53
54 268 nor after adjustment for TV time, exercise time and energy intake (results not shown).

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3 269 In stratified analyses no difference in annualised WC gain between the two periods was
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5 270 observed for women, those aged <55 years, those in the highest education group, those with
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7 271 normal weight nor ex-smokers. Annualised WC gain was less in Period 2 than Period 1 for
8
9 272 those in the tertile of least area-level socio-economic disadvantage (-0.14cm/year 95%CI -
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11 273 .05, -0.23).

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14 274 (Table 4 here)

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18 275 For both weight and WC, there was an apparent combined sex and age effect, such that older
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20 276 men had the least favourable changes over time (Figure 1).

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23 277 The primary analyses were repeated after excluding the few participants with annual weight
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25 278 change greater than 5 kg/y or less than -5 kg/y, and restricting participants to the overlapping
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27 279 age group of 30–80. No differences in results were seen.

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35 36 282 **DISCUSSION**

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39 283 In this analysis of a single cohort of Australian adults, weight and WC increased in the most
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41 284 recent period in all population sub-groups examined. Age-adjusted annualised weight gain
42
43 285 between 2005–2012 was less than between 1999/2000–2005, but annualised WC gain was
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45 286 greater. Lesser weight gain over time was not seen in older men or those with greatest area-
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47 287 level socio-economic disadvantage.

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54 289 The lack of difference in weight and WC change between the two periods observed for
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56 290 current smokers, those from a non-English speaking background and those with obesity, is

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3 291 likely to reflect small sample sizes in these groups. In general, adjustment for covariates had
4
5 292 little effect on the observed associations between study period and weight and WC change.
6
7 293 As time spent watching TV, exercise and energy intake might be expected to be mediating
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9 294 much of the observed changes, we had expected an observable reduction in the difference
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11 295 between study periods after adjustment for these factors. The lack of impact after adjustment
12
13 296 likely reflects that they are relatively blunt instruments to detect small changes in behaviour
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15 297 over time. The self-reported nature of these behavioural questionnaires is associated with
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17 298 both differential and non-differential error [18] [19]. While validated, the FFQ is has a
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19 299 limited list of foods and is affected by the inability of individuals to accurately report their
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21 300 food intake retrospectively over a long period of time [20]. Further the Active Australia
22
23 301 questionnaire only refers to leisure time activity and TV watching is only one component of
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25 302 sitting time.
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29 303
30 304 The general observation that weight gain may be lessening over time supports the cross-
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32 305 sectional time series observations of a plateau in the prevalence of obesity and rate of change
33
34 306 in BMI [4]. However, these results also suggest that the general observations do not tell the
35
36 307 whole story, with large differences between different population subgroups, and a contrasting
37
38 308 observation for waist circumference. The sex differences observed here are similar to the
39
40 309 cross-sectional trends reported for American adults for whom a clear plateau in obesity
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42 310 prevalence has been observed for women but not men [5]. The differences we observed
43
44 311 according to level of area-level socio-economic disadvantage also reflect findings from the
45
46 312 review of obesity trends in which the levelling off of obesity was generally more pronounced
47
48 313 in groups with higher socio-economic position [4]. It will be important to do a similar
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50 314 analysis in a longitudinal children's cohort, as their experience is likely to differ from that of
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52 315 adults. Children have been exposed to a wide range of obesity prevention interventions,
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3 316 particularly in schools, in countries such as Australia and cross-sectional trends clearly
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5 317 suggest a plateauing in the prevalence of obesity in children [4].
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8 318 The observation that rates of WC change may be continuing to increase even as rates of
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10 319 weight change decrease may reflect prior findings using the NHANES data that WC is
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12 320 increasing to a greater extent than expected from changes in weight [21] [22]. While we
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14 321 observed changes in weight and WC to be highly correlated these results combined suggest a
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16 322 preferential increase in abdominal adiposity over time, which is thought to be associated with
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18 323 greater risk of cardio-metabolic outcomes [23]. The potential implication that current
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20 324 bodyweight trends are leading a more metabolically active obesity, with increased risks for
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22 325 outcomes such as diabetes, hypertension and cardiovascular disease warrants further
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24 326 investigation.
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29 327 The key strength of the current study is that for the first time it addresses this important
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31 328 question through an analysis of the same cohort of adults over two distinct but recent time
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33 329 periods, independent of the effects of ageing. In doing this, conclusions can be drawn about
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35 330 the changes over time independent of unmeasurable differences in cohorts. Other strengths
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37 331 include the national population sampling strategy of the AusDiab cohort and the measured
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39 332 weight and WC at each study wave.
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43 333 The potential limitation of the current study is the lack of generalisability of the included
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45 334 cohort. As with all cohort studies, the AusDiab cohort is a selected population, and those who
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47 335 attended all three waves are more select again, with higher educational attainment and a
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49 336 lower prevalence of chronic disease and risk factors. It is possible that a generally more
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51 337 healthy and health conscious population has a stronger response to population health
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53 338 messages, and consequently the lesser weight gain observed here in consecutive age cohorts
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55 339 over time may be greater than would be observed for the general population. However, the
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3 340 current observations lend support to the concept that weight gain is decreasing over time in
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5 341 the population, even if the AusDiab cohort represents a particularly sensitive indicator. One
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7 342 further potential limitation is the use of different weighing scales at AusDiab 2 and 3
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10 343 compared to AusDiab1. Although all scales were calibrated in the same way at each survey
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12 344 wave, differences in variability between the scales may have led to more variability in the
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14 345 change in weight in Period 1 than Period 2.

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17 346 The results also suggest there is no room for complacency in obesity prevention. The rates of
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19 347 overweight and obesity remain high, the average change in weight and WC remains an
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21 348 increase and there is no reduction in the rate of WC gain. Further, no decrease in the rate of
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23 349 weight or WC change were observed in older men. Finally, the observation that no decrease
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25 350 in rates of weight and WC change is being seen by those living in the most socially
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28 351 disadvantaged neighbourhoods suggests current trends are likely to lead to an increase in the
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30 352 social inequalities in obesity, and consequent ill health [24]. It is critical that further studies
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32 353 are conducted to confirm these findings and that we work to identify the causes of the
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34 354 observed changes, including the differences observed in specific population sub-groups.

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38 355 In summary, between 2004/5 and 2011/2 Australian adults continued to gain weight: WC at a
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40 356 faster rate than between 1999/2000 and 2004/4, and weight at a slower rate. While weight
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42 357 gain may be slowing, it does not appear to be affecting older men or those in more
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44 358 disadvantaged groups, and the same cannot be said for WC.

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367 **References**

- 368 1. International Association for the Study of Obesity. Obesity the global epidemic. Secondary
369 Obesity the global epidemic 2013.
370 <http://www.iaso.org/iotf/obesity/obesitytheglobalepidemic/>.
- 371 2. Stamatakis E, Zaninotto P, Falaschetti E, Mindell J, Head J. Time trends in childhood and
372 adolescent obesity in England from 1995 to 2007 and projections of prevalence to
373 2015. *J Epidemiol Community Health* 2010;**64**(2):167-74 doi:
374 10.1136/jech.2009.098723[published Online First: Epub Date]].
- 375 3. Sundblom E, Petzold M, Rasmussen F, Callmer E, Lissner L. Childhood overweight and
376 obesity prevalences levelling off in Stockholm but socioeconomic differences persist.
377 *Int J Obes (Lond)* 2008;**32**(10):1525-30 doi: 10.1038/ijo.2008.104[published Online
378 First: Epub Date]].
- 379 4. Rokholm B, Baker JL, Sorensen TI. The levelling off of the obesity epidemic since the
380 year 1999--a review of evidence and perspectives. *Obes Rev* 2010;**11**(12):835-46 doi:
381 10.1111/j.1467-789X.2010.00810.x[published Online First: Epub Date]].
- 382 5. Flegal KM, Carroll MD, Kit BK, Ogden CL. Prevalence of obesity and trends in the
383 distribution of body mass index among US adults, 1999-2010. *JAMA*
384 2012;**307**(5):491-7 doi: 10.1001/jama.2012.39[published Online First: Epub Date]].
- 385 6. Statistics ABo. Australian Health Survey: First Results, 2011-12. Canberra: Australian
386 Bureau of Statistics, 2012.
- 387 7. Dunstan DW, Zimmet PZ, Welborn TA, et al. The Australian Diabetes, Obesity and
388 Lifestyle Study (AusDiab)--methods and response rates. *Diabetes Res Clin Pract*
389 2002;**57**(2):119-29
- 390 8. Cameron AJ, Welborn TA, Zimmet PZ, et al. Overweight and obesity in Australia: the
391 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab). *Med J Aust*
392 2003;**178**(9):427-32
- 393 9. Risk Factor Prevalence Management Committee. Risk factor prevalence study No.3, 1989:
394 National Heart Foundation and Australian Institute of Health, 1990.
- 395 10. Williams ED, Magliano DJ, Zimmet PZ, et al. Area-level socioeconomic status and
396 incidence of abnormal glucose metabolism: the Australian Diabetes, Obesity and
397 Lifestyle (AusDiab) study. *Diabetes Care* 2012;**35**(7):1455-61 doi: 10.2337/dc11-
398 1410[published Online First: Epub Date]].

- 1
2
3 399 11. Statistics ABo. Information Paper - Census of Population and Housing: Socio-Economic
4 400 Indexes for Areas Australia 2001. : Australian Bureau of Statistics, 2001.
5
6 401 12. Australian Institute of Health and Welfare. The Active Australia Survey. A guide and
7
8 402 manual for implementation, analysis and reporting. Canberra: Australian Institute of
9
10 403 Health and Welfare, 2003.
11 404 13. Armstrong T, Bauman A, Davies J. Physical activity patterns of Australian adults. Results
12 405 of the 1999 National Physical Sctivity Survey. Australian Institute of Health and
13 406 Welfare cat No CVD10. Canberra: Australian Institute of Health and Welfare, 2000.
14
15 407 14. Salmon J, Bauman A, Crawford D, Timperio A, Owen N. The association between
16 408 television viewing and overweight among Australian adults participating in varying
17 409 levels of leisure-time physical activity. *Int. J. Obes. Relat. Metab. Disord.*
18 410 *2000;24:600-6*
19
20 411 15. Ireland P, Jolley D, Giles G, et al. Development of the Melbourne FFQ: A food frequency
21 412 questionnaire for use in an Australian prospective study involving an ethnically
22 413 diverse cohort. *Asia Pacific J Clin Nutr* 1994;**3**:19-31
23
24 414 16. Briganti EM, Shaw JE, Chadban SJ, et al. Untreated hypertension among Australian
25 415 adults: the 1999-2000 Australian Diabetes, Obesity and Lifestyle Study (AusDiab).
26 416 *Med J Aust* 2003;**179**(3):135-9
27
28 417 17. Magliano DJ, Barr EL, Zimmet PZ, et al. Glucose indices, health behaviors, and
29 418 incidence of diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle
30 419 Study. *Diabetes Care* 2008;**31**(2):267-72 doi: 10.2337/dc07-0912[published Online
31 420 First: Epub Date]].
32
33 421 18. Hebert JR, Hurley TG, Peterson KE, et al. Social desirability trait influences on self-
34 422 reported dietary measures among diverse participants in a multicenter multiple risk
35 423 factor trial. *J Nutr* 2008;**138**(1):226S-34S
36
37 424 19. Booth ML, Owen N, Bauman AE, Gore CJ. Retest reliability of recall measures of
38 425 leisure-time physical activity in Australian adults. *Int J Epidemiol* 1996;**25**(1):153-9
39
40 426 20. Dodd KW, Guenther PM, Freedman LS, et al. Statistical methods for estimating usual
41 427 intake of nutrients and foods: a review of the theory. *J Am Diet Assoc*
42 428 *2006;106*(10):1640-50 doi: 10.1016/j.jada.2006.07.011[published Online First: Epub
43 429 Date]].
44
45 430 21. Elobeid MA, Desmond RA, Thomas O, Keith SW, Allison DB. Waist circumference
46 431 values are increasing beyond those expected from BMI increases. *Obesity (Silver*
47
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3 432 Spring) 2007;**15**(10):2380-3 doi: 15/10/2380 [pii]10.1038/oby.2007.282[published
4 433 Online First: Epub Date]].
5
6
7 434 22. Walls HL, Stevenson CE, Mannan HR, et al. Comparing trends in BMI and waist
8 435 circumference. *Obesity (Silver Spring)* 2011;**19**(1):216-9 doi: oby2010149 [pii
9 436 10.1038/oby.2010.149[published Online First: Epub Date]].
10
11
12
13 437 23. Welborn TA, Dhaliwal SS, Bennett SA. Waist-hip ratio is the dominant risk factor
14 438 predicting cardiovascular death in Australia. *Med J Aust* 2003;**179**(11-12):580-5
15
16 439 24. Backholer K, Mannan HR, Magliano D, et al. Projected socioeconomic disparities in the
17 440 prevalence of obesity amongst Australian adults. *Australian and New Zealand Journal*
18 441 *of Public Health* 2012;**in press**
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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.

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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 ($p < 0.05$)

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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)*

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5	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)
6						
7	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)
8						
9	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)*
10						
11	Education- secondary & trade					
12	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)*
13						
14	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)
15						
16						
17	Area level disadvantage- tertile	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)*
18	of most disadvantage					
19	Area level disadvantage-	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)*
20	middle tertile					
21	Area level disadvantage- tertile					
22	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)*
23						
24	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)
25						
26	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)
27						
28	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)
29						
30						
31	English speaking country of					
32	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)*
33						
34	Non-English speaking country					
35	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)
36						
37	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)*
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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

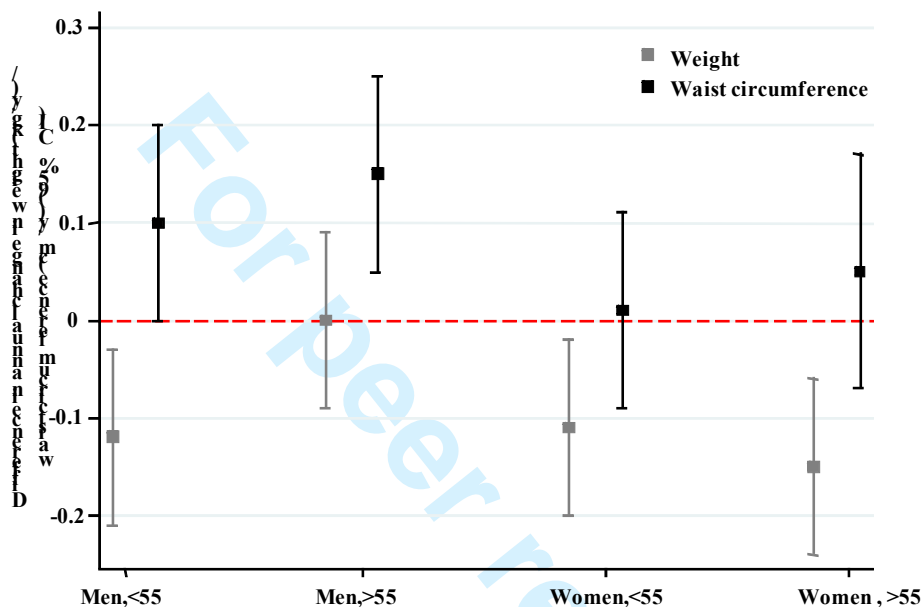
Model 2- additionally adjusting for smoking status, education status, area-level disadvantage and ethnicity

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.

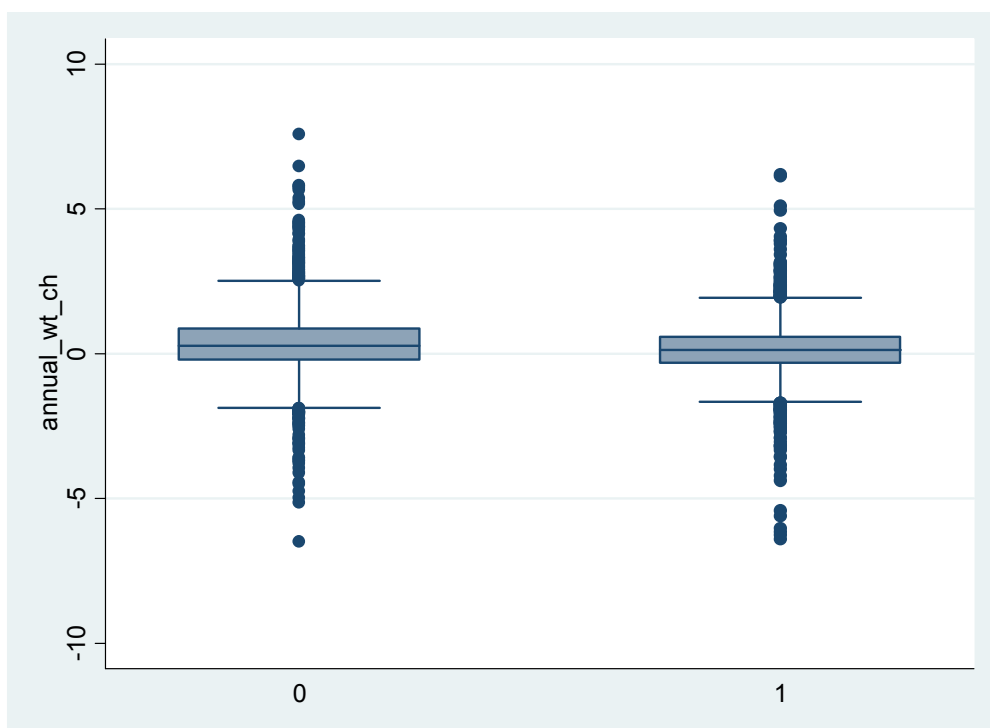


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Appendix

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

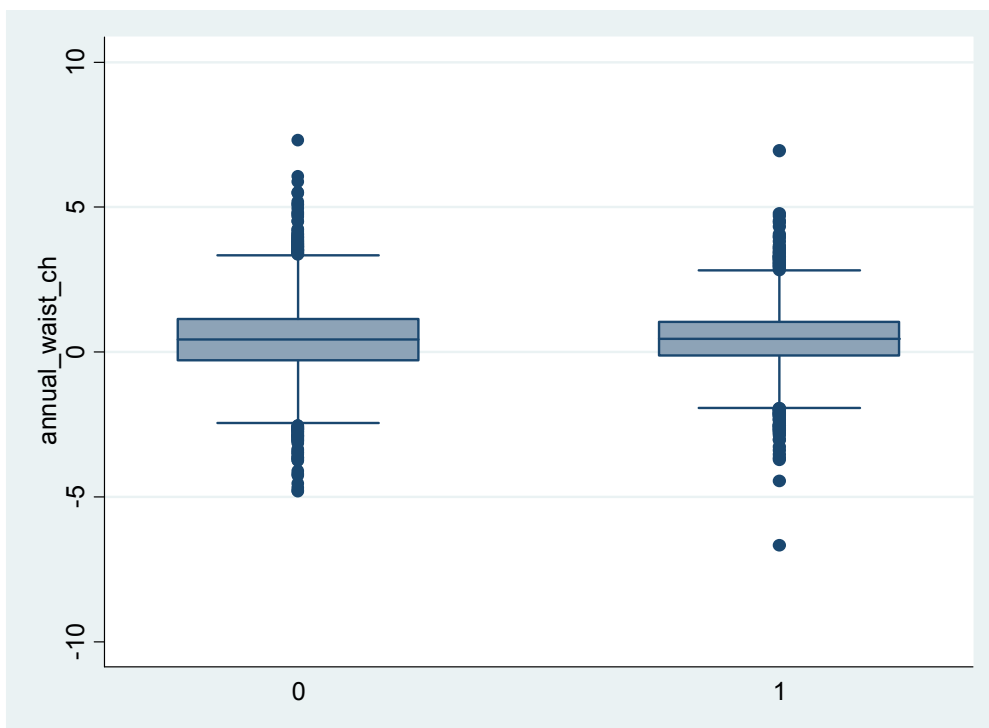
A. Annualised weight change



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B. Annualised waist circumference change

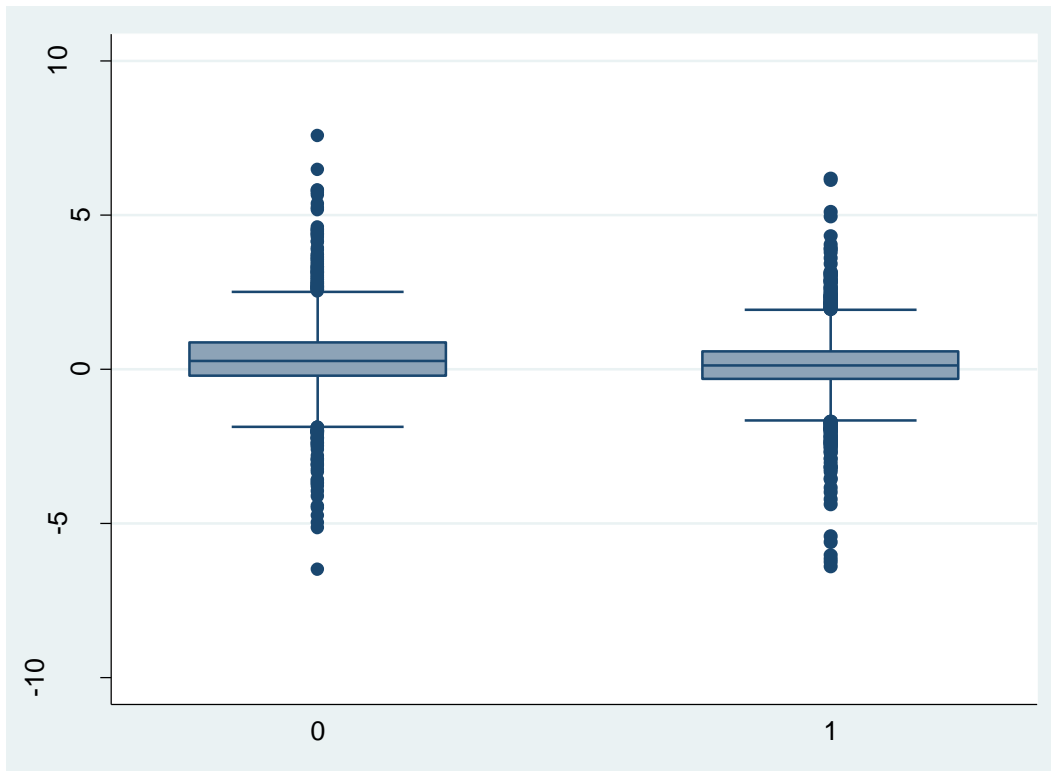


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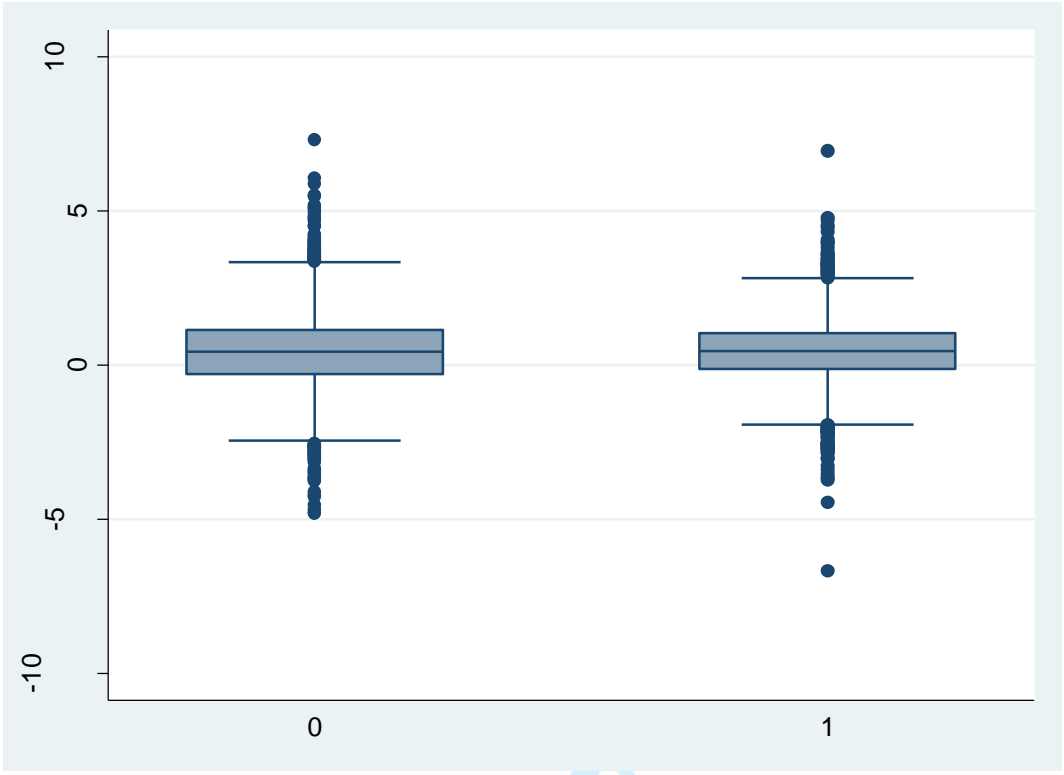
Figure 1 Annual weight and waist circumference change in Period 1 and Period 2

A. Annual weight change



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B. Annual waist circumference change



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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)
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.

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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>.

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