

# Patterns and demographic predictors of 5-year weight change in a multi-ethnic cohort of men and women in Australia

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## Abstract

*Objective:* This study investigated 5-year trends in body weight, overweight and obesity and their association with sociodemographic variables in a large, multi-ethnic community sample of Australian adults.

*Design:* This prospective population study used baseline and 5-year follow-up data from participants in the Melbourne Collaborative Cohort Study (MCCS).

*Setting:* Population study in Melbourne, Australia.

*Subjects:* In total, 12 125 men and 17 674 women aged 35–69 years at baseline.

*Results:* Mean 5-year weight change in this sample was +1.58 (standard deviation (SD) 4.82) kg for men and +2.42 (SD 5.17) kg for women. Younger (35–44 years) men and, in particular, women gained more weight than older adults and were at highest risk of major weight gain ( $\geq 5$  kg) and becoming overweight. Risk of major weight gain and associations between demographic variables and weight change did not vary greatly by ethnicity. Education level showed complex associations with weight outcomes that differed by sex and ethnicity. Multivariate analyses showed that, among men, higher initial body weight was associated with decreased likelihood of major weight gain, whereas among women, those initially overweight or obese were about 20% more likely to experience major weight gain than underweight or healthy weight women.

*Conclusions:* Findings of widespread weight gain across this entire population sample, and particularly among younger women and women who were already overweight, are a cause for alarm. The prevention of weight gain and obesity across the entire population should be an urgent public health priority. Young-to-mid adulthood appears to be a critical time to intervene to prevent future weight gain.

**Keywords**  
Weight change  
Population  
Longitudinal  
Obesity

Overweight and obesity impact negatively on health, increasing the risk of morbidity and/or mortality from a number of chronic conditions including type 2 diabetes mellitus, coronary heart disease, hypertension, hyperlipidaemia, osteoarthritis and certain cancers<sup>1</sup>. The psychological, social and economic impacts of obesity are also substantial<sup>1</sup>. It is therefore of grave concern that the prevalences of obesity and weight gain are increasing world-wide. For example, cross-sectional and longitudinal data from the US National Health and Nutrition Examination Surveys (NHANES)<sup>2–4</sup> show major recent increases in the prevalence of obesity and incidence of weight gain across the US population. Data from the first NHANES follow-up study of 3727 men and 6135 women aged 25–74 years at baseline (1971–75) showed that weight gain over time was common. Over a 10-year period, major weight gain (an increase in body mass index (BMI) of  $5 \text{ kg m}^{-2}$  or more) was experienced by 2.3% of males and 5.3% of females<sup>2</sup>. More recent data suggested that the prevalence of obesity continued to rise between

1976–80 and 1988–94<sup>5</sup>. Data from England<sup>6,7</sup>, Finland<sup>8,9</sup>, Sweden<sup>10</sup> and several European countries<sup>11,12</sup> also reflect this trend towards increasing weight gain and obesity, and suggest that weight gain throughout much of adult life is common.

While obesity is increasing across entire populations, some population groups appear to be at increased risk. The NHANES I data show that the incidence of major weight gain over a 10-year period was twice as high in women as in men. Younger women (aged 25–44 years) and women who were initially overweight had the highest incidence of major weight gain<sup>2,4</sup>. Similarly, a Dutch cohort study<sup>13</sup> showed that women reported larger increases in BMI than males over a 6-year follow-up. Although longitudinal data are lacking in Australia, the available cross-sectional data suggest that the proportion of overweight or obese men increased by 23% between 1980 and 1989; the corresponding increase among women was 58%<sup>14</sup>.

Some evidence suggests that individuals of lower socio-economic status (SES) are also at increased risk of weight

gain. US data show that the rate of weight gain is disproportionately higher in low SES groups<sup>15</sup>. Finnish data showed that between 1966–72 and 1973–76, risk of major weight gain (5 kg or more) was highest among those who were less educated<sup>16</sup>. Another Finnish study showed an inverse relationship between SES and BMI, with BMI differences between educational groups becoming wider among men and, in particular, women during 1972–1992<sup>17</sup>. However, a Swedish longitudinal study showed that SES was inversely related to change in BMI among men, but not among women<sup>10</sup>. In addition, a Dutch cohort study showed that whilst SES was inversely related to BMI cross-sectionally, it was not longitudinally associated with BMI change<sup>13</sup>. Ethnicity/race has also been found to be associated with risk of weight gain<sup>10,18</sup>, although again findings are equivocal<sup>19</sup>.

Longitudinal data on weight change in large population-based samples are scarce. Additional longitudinal data are required to investigate patterns of weight gain among population subgroups and to identify those groups at highest risk. The aim of this study was to investigate patterns of weight change, the incidences of major weight gain, overweight and obesity, and how these vary by sex, age, education and initial body mass, in a large cohort of men and women aged 35 years and over from multiple countries of birth.

## Methods

### Participants

Data were provided by 29 799 (12 125 male and 17 674 female) participants in the Melbourne Collaborative Cohort Study (MCCS), a prospective epidemiological study of the relationship between diet, anthropometry, lifestyle and health<sup>20</sup>. The MCCS was established to address the major causes of premature death and chronic morbidity in Australia, specifically cancer, coronary heart disease and diabetes mellitus. Participants aged 35 to 69 years were recruited from throughout metropolitan Melbourne, a city of 3 million people, between November 1990 and October 1994. Recruitment was accomplished largely by personal letters of invitation using the Australian electoral rolls. Baseline data were provided by a total of 41 530 adults. A quarter of the 41 234 participants for whom a complete set of reliable anthropometric measurements was available at baseline were born in southern Europe: 5377 Italian-born, 4459 Greek-born and 390 Maltese-born. The over-sampling of southern European migrants was done deliberately to extend the range of dietary exposures and to study groups at different risk for the diseases of interest. Because information on personal ethnicity was not collected, country of birth was used as an indicator of ethnicity. The term 'Anglo-Celtic' has been used to refer collectively to men and women born in Australia ( $n = 28\,118$ ), England ( $n = 1922$ ), Scotland ( $n = 426$ ), New Zealand ( $n = 269$ ), Ireland

( $n = 201$ ) and Wales ( $n = 72$ ). In Australia, Anglo-Celts comprise the largest ethnic population group. Among other migrant groups in Australia, Italians and Greeks comprise two of the larger groups.

Of the baseline respondents, 35 704 (86%) also completed a 5-year follow-up survey. Of these, 29 799 provided usable height and weight data at baseline and follow-up, and data for these participants are included in the present study. Of the 29 799 respondents in the final sample, 23 219 (77.9%) were Anglo-Celtic; 3626 (12.2%) were Italian or Maltese; and 2954 (9.9%) were Greek. Educational attainment was classified into four levels with 16.4% having completed primary school only, 37.8% some secondary school, 18.0% having completed secondary school and 27.8% being tertiary-educated. Comparisons of this sample with baseline respondents on demographic and weight-related measures showed that those in the final sample were slightly more likely to be Anglo-Celtic and tertiary-educated, and slightly less likely to be obese, but these differences were not large ( $\phi \leq 0.15$ ).

### Measures

Participants' height and weight were measured at baseline in light indoor clothing without shoes. Height was recorded to the nearest millimetre on subjects in the standing position, using wall-mounted stadiometers. Weight was recorded to the nearest tenth of a kilogram using electronic scales. At follow-up, weight was collected by self-report. To adjust for biases typically encountered using self-reported weight, a correction was applied to follow-up weight data. Based on sex- and age-specific comparisons of self-report and objective weight in the Australian National Nutrition Survey<sup>21</sup>, corrected weight was calculated as follows:  $(1.002 \times \text{self-reported weight}) - (0.037 \times \text{age at follow-up}) + 4.179$  for men; and  $(1.039 \times \text{self-reported weight}) + 0.205$  for women. BMI was computed as weight in kilograms (objective at baseline; corrected self-report at follow-up) divided by the square of baseline height in metres. BMI was categorised as 'underweight' ( $\text{BMI} < 20 \text{ kg m}^{-2}$ ), 'healthy weight' ( $\text{BMI} = 20\text{--}25 \text{ kg m}^{-2}$ ), 'overweight' ( $\text{BMI} > 25\text{--}30 \text{ kg m}^{-2}$ ) and 'obese' ( $\text{BMI} > 30 \text{ kg m}^{-2}$ ), according to the Australian National Health and Medical Research Council classification system<sup>22</sup>. Smoking status was assessed with the questions 'Do you now smoke at least 7 cigarettes a week?' and 'Have you ever smoked at least 7 cigarettes a week for at least a year?' Respondents were categorised as 'current smokers', 'ex-smokers' and 'never smokers'.

Weight change was calculated as corrected follow-up weight minus baseline weight. Weight change was also categorised into nine groups, as follows: lost 10 or more kg, lost 5–10, 2–5, 1–2 kg, within 1 kg, gained 1–2, 2–5, 5–10 kg, gained 10 kg or more. Major weight gain was classified as a gain of 5 kg or more. Weight change (both continuous and categorical), rather than BMI change, was used as an outcome measure to facilitate interpretability of

the data. Using BMI category change as an outcome has the limitation that, for some individuals (i.e. those whose baseline weight placed them near the BMI category cut-off points), change in BMI category could result from relatively small weight gain or loss, whereas for others a larger weight change would be required. Hence the predictors of change in BMI category may differ from those predicting weight change. The use of weight change also enabled an investigation of predictors of small weight changes within broader BMI categories (for instance, the predictors of weight gains among those already obese).

The proportions of men and women who became overweight, and were neither overweight nor obese at baseline (i.e. those who were either underweight or normal weight at baseline and overweight at follow-up), as well as those who became obese at follow-up (and were not at baseline), were also examined.

### Statistical analyses

Data were analysed using SPSS for Windows statistical software, version 11.0.0<sup>23</sup>. Descriptive statistics (mean, standard deviation (SD)) were used to investigate 5-year weight change. Analyses of variance were used to investigate univariate associations between demographic variables and weight change. Cross-tabulations and chi-square analyses were used to examine demographic differences among categories of weight change, and among new cases (incidence) of overweight/obesity. Incidence of overweight and obesity was defined as the percentage of respondents who gained weight to become overweight or obese at follow-up. Separate linear regression models were used to investigate the relative

contributions of age, education level and initial BMI in predicting weight change over time among men and women. Separate logistic regression models were used to examine the relative contributions of the same variables to predicting major weight gain over time. Both linear and logistic regression models controlled for smoking status, which was strongly related to both the predictor and outcome variables in the models.

### Results

At baseline, 1.1% of men and 4.1% of women were underweight; 28.2% of men and 41.0% of women were in the healthy weight range; 53.2% of men and 35.7% of women were overweight; and 17.5% of men and 19.2% of women were obese. Table 1 shows the distribution of BMI categories by age group, education level and ethnicity among men and women at baseline. Baseline BMI category was significantly associated with all three demographic variables for both men and women ( $P < 0.01$ ). Prevalences of overweight and obesity were highest among those aged 55 and over, those with primary education and those born in Greece, Italy or Malta.

Over the 5-year study period, women gained (2.42 (SD 5.17) kg) significantly ( $P < 0.01$ ) more weight than men (1.58 (SD 4.82) kg). Within each ethnic group, women gained significantly more weight than men ( $P < 0.01$ ). Mean weight changes were 1.54 (SD 4.90) kg and 2.35 (SD 5.25) kg, respectively, for Anglo-Celtic men and women; 1.82 (SD 4.66) kg and 2.68 (SD 4.89) kg, respectively, for Greek men and women; and 1.64 (SD 4.50) kg and 2.69 (SD 4.74) kg, respectively, for Italian/Maltese men and women.

**Table 1** Percentages of men and women in each category of body mass index (BMI) at baseline, by age group, education level and ethnicity

	BMI category†							
	Men (%)				Women (%)			
	Underweight <i>n</i> = 134	Healthy weight <i>n</i> = 3420	Overweight <i>n</i> = 6449	Obese <i>n</i> = 2119	Underweight <i>n</i> = 724	Healthy weight <i>n</i> = 7238	Overweight <i>n</i> = 6311	Obese <i>n</i> = 3400
<b>Age group (years)</b>								
35–44‡	1.9	36.1	48.3	13.7*	5.9	52.8	27.6	13.7*
45–54	1.0	29.3	52.7	16.9	3.9	43.6	33.9	18.6
55–64	0.9	24.4	54.8	20.0	3.3	33.5	39.8	23.4
65 or over	0.9	26.7	55.4	17.0	3.8	38.5	39.5	18.3
<b>Education</b>								
Primary	0.4	12.8	57.3	29.5*	1.0	16.7	43.0	39.3*
Some secondary	1.0	25.2	54.1	19.7	3.9	40.4	37.5	18.2
Completed secondary	0.9	27.6	55.1	16.4	5.0	47.1	33.4	14.6
Tertiary	1.6	38.7	49.2	10.5	5.7	54.7	29.0	10.5
<b>Ethnic group</b>								
Anglo-Celtic	1.4	33.2	51.3	14.1*	4.9	46.5	33.9	14.6*
Greek	0.4	12.8	58.7	28.0	0.6	16.4	45.3	37.8
Italian/Maltese	0.1	13.5	59.0	27.4	1.0	21.3	40.6	37.0

\*  $P < 0.01$  for association between demographic variable and baseline BMI category.

† Underweight – BMI  $< 20 \text{ kg m}^{-2}$ ; healthy weight – BMI =  $20\text{--}25 \text{ kg m}^{-2}$ ; overweight – BMI  $> 25\text{--}30 \text{ kg m}^{-2}$ ; obese – BMI  $> 30 \text{ kg m}^{-2}$ .

‡ Individuals in the 35–44 year age group were primarily aged over 40, with 34 men and 91 women aged 35–39.

**Table 2** Mean and standard deviation (SD) of weight change in kg by age group, education, baseline category of body mass index (BMI) and ethnicity

	Mean weight change (SD) (kg)					
	Anglo-Celtic		Greek		Italian/Maltese	
	Men <i>n</i> = 9122	Women <i>n</i> = 14 097	Men <i>n</i> = 1363	Women <i>n</i> = 1591	Men <i>n</i> = 1640	Women <i>n</i> = 1986
Age group (years)						
35–44	3.06 (4.92)*	3.15 (4.91)*	2.95 (4.28)*	3.55 (5.12)*	3.32 (4.00)*	3.70 (4.86)*
45–54	2.11 (4.95)	2.96 (5.47)	2.43 (4.74)	2.93 (4.55)	2.27 (4.20)	3.12 (4.76)
55–64	0.97 (4.68)	2.05 (5.15)	1.57 (4.62)	2.34 (4.81)	1.23 (4.60)	2.30 (4.53)
65 or over	0.08 (4.59)	1.03 (5.13)	0.60 (4.44)	1.48 (6.54)	0.50 (4.55)	1.68 (4.99)
Education						
Primary	1.03 (4.39)*	2.04 (5.88)	1.62 (4.85)	2.73 (4.84)	1.41 (4.75)	2.50 (4.85)
Some secondary	1.37 (5.07)	2.34 (5.40)	2.30 (4.41)	2.44 (5.35)	2.09 (4.06)	3.08 (4.69)
Completed secondary	1.35 (5.11)	2.30 (5.19)	2.13 (4.39)	2.45 (4.63)	1.46 (4.75)	3.11 (4.12)
Tertiary	1.82 (4.65)	2.51 (4.99)	1.70 (3.85)	3.56 (4.70)	1.78 (3.78)	3.01 (4.16)
Baseline BMI category†						
Underweight‡	4.26 (3.71)*	3.18 (3.37)*	2.63 (6.64)*	4.88 (3.83)*	13.58 (7.35)*	4.02 (6.17)*
Healthy weight	2.53 (4.34)	2.79 (4.52)	3.55 (3.68)	3.62 (3.89)	3.36 (3.87)	3.57 (3.77)
Overweight	1.25 (4.62)	2.15 (5.29)	1.99 (4.19)	3.13 (3.91)	1.77 (4.25)	2.82 (4.53)
Obese	0.00 (6.41)	1.14 (7.24)	0.65 (5.59)	1.70 (6.06)	0.44 (4.89)	2.00 (5.31)

\*  $P < 0.01$ .† Underweight – BMI < 20 kg m<sup>-2</sup>; healthy weight – BMI = 20–25 kg m<sup>-2</sup>; overweight – BMI > 25–30 kg m<sup>-2</sup>; obese – BMI > 30 kg m<sup>-2</sup>.

‡ Underweight was combined with healthy weight for analysis of variance owing to small numbers of underweight subjects.

Table 2 shows the univariate associations between age group, education level, baseline weight category and weight change (kg), by sex and ethnicity. Those in younger age groups gained significantly more weight than older groups, with those aged 35–44 years gaining the most weight within every sex or ethnic group. Education level was not significantly associated with weight gain, except among Anglo-Celtic men, with those who were tertiary-educated gaining most weight. Baseline weight status was significantly associated with weight gain in every sex and ethnic group, with those who were underweight or in a healthy weight range at baseline generally gaining the most weight. However, overweight and obese respondents – particularly women – also reported weight gains.

The proportions of men and women in each category of weight change, and the associations between age group, education level, baseline BMI category and category of weight change by ethnic group, are provided in Tables 3 (men) and 4 (women). Among men across all three ethnic groups, younger men were more likely to report larger weight gains ( $P < 0.01$  for all groups), with men aged 35–44 more likely than any other age group to have gained 2–4.99 kg, 5–9.99 kg or 10 kg or more. Men aged over 55 were most likely to have maintained their weight. Education level was not associated with weight change for Greek ( $P = 0.23$ ) or Italian/Maltese ( $P = 0.13$ ) men. Among Anglo-Celtic men, those who were primary-educated were the most likely to have maintained their weight, and those who were tertiary-educated were most likely to report small to moderate gains (2–9.99 kg) ( $P < 0.01$ ). Baseline weight status was significantly associated with men's weight change category ( $P < 0.01$ ) across all

three ethnic groups, with those underweight or in the healthy weight range at baseline being generally more likely to experience larger weight gains, and those initially overweight or obese being generally more likely to maintain their weight or lose weight, although a proportion had continued to gain weight.

Somewhat different patterns of weight change were observed among women. Similar to age trends among men, younger women ( $P < 0.01$  for all ethnic groups) were more likely to experience moderate to large weight gains (Table 4). However, education level was not associated with weight gain among women in any ethnic group. Patterns of weight gain by baseline BMI category among women were complex. Unlike the men, obese Anglo-Celtic women were more likely to gain 10 kg or more than were all other women, and overweight women were also more likely to gain 10 kg or more than were healthy weight or underweight women. Across all three ethnic groups, however, overweight and obese women also tended to be more likely than other women to report major weight loss (particularly 10 kg or more). Nonetheless, obese women were still more likely to report moderate to large weight gain than moderate to large weight loss.

A total of 9.2% of men and 11.4% of women gained enough weight to become overweight, and 6.6% of men and 7.3% of women gained enough to become obese during the study period. Tables 5 and 6 show the percentages of men and women becoming overweight or obese overall and by age group, education level, baseline BMI category and ethnicity. Among men in all three ethnic groups (Table 5), those who were younger were generally more likely to become overweight. Age group was

**Table 3** Percentages of men in each category of weight change (kg) by age group, education, baseline category of body mass index (BMI) and ethnicity

	Category of weight change								P-value	
	Gained 10kg or more				Lost 10kg or more					
	Gained 5-9.99kg	Gained 2-4.99kg	Gained 1-1.99kg	Within 0.99kg	Lost 1-1.99kg	Lost 2-4.99kg	Lost 5-9.99kg	Lost 10kg or more		
<b>Overall % for men in all three ethnic groups</b>	3.4	15.8	27.0	11.0	18.2	6.7	11.2	5.3	1.4	
<b>ANGLO-CELTIC</b>										
Overall % for Anglo-Celtic men	3.5	15.7	26.7	10.8	18.4	6.7	11.2	5.6	1.5	
Age group (years)										
35-44 (n = 1663)	6.3	24.0	29.9	9.8	14.0	4.7	7.3	3.2	0.9	<0.01
45-54 (n = 2803)	4.2	18.8	29.8	9.4	17.1	5.9	8.9	4.5	1.4	
55-64 (n = 2966)	2.2	12.3	25.7	11.9	20.4	7.0	12.5	6.3	1.7	
65 or over (n = 1690)	1.5	8.2	20.3	12.3	21.5	9.2	16.4	8.6	1.8	
Education										
Primary (n = 253)	3.2	14.2	19.8	10.7	21.7	9.5	13.8	5.9	1.2	<0.01
Some secondary (n = 2984)	3.5	15.7	25.4	9.9	19.0	6.6	11.9	6.0	2.0	
Completed secondary (n = 2157)	3.4	15.6	26.2	10.4	17.2	7.2	11.8	6.4	1.7	
Tertiary (n = 3728)	3.5	15.9	28.5	11.8	18.4	6.2	10.0	4.9	0.9	
Baseline BMI category*										
Underweight† (n = 127)	7.9	24.4	42.5	7.9	15.0	0.0	1.6	0.8	0.0	<0.01
Healthy weight (n = 3024)	3.7	19.0	32.0	12.1	17.4	5.5	7.1	2.6	0.5	
Overweight (n = 4682)	2.9	13.8	25.3	10.6	20.3	7.0	13.1	5.9	1.1	
Obese (n = 1287)	4.2	13.8	17.9	8.9	14.3	8.9	14.7	12.3	5.1	
<b>GREEK</b>										
Overall % for Greek men	3.7	16.4	29.3	10.7	16.1	6.4	11.4	4.5	1.4	
Age group (years)										
35-44 (n=109)	5.5	22.0	40.4	9.2	7.3	1.8	9.2	4.6	0.0	<0.01
45-54 (n=454)	5.5	18.9	31.1	8.8	13.2	6.8	11.7	2.6	1.3	
55-64 (n=587)	3.1	15.0	29.0	11.2	18.1	6.8	10.6	4.8	1.5	
65 or over (n=213)	0.9	12.2	21.1	14.1	21.1	6.6	14.1	8.0	1.9	
Education										
Primary (n=836)	3.9	16.6	27.0	10.9	15.8	6.2	12.7	5.1	1.7	0.23
Some secondary (n=216)	3.7	18.5	32.9	7.4	14.4	7.9	10.2	4.6	0.5	
Completed secondary (n=227)	3.1	16.3	32.6	11.5	16.7	5.7	11.0	1.8	1.3	
Tertiary (n=84)	3.6	9.5	34.5	15.5	21.4	6.0	2.4	6.0	1.2	
Baseline BMI category*										
Underweight† (n = 5)	0.0	60.0	0.0	0.0	20.0	0.0	0.0	20.0	0.0	<0.01
Healthy weight (n = 175)	5.1	25.7	31.4	14.3	14.9	4.6	4.0	0.0	0.0	
Overweight (n = 800)	3.5	15.8	32.1	10.9	16.0	6.9	11.6	2.3	1.0	
Obese (n = 382)	3.7	13.1	22.8	8.9	16.8	6.3	14.4	11.3	2.9	

Table 3. Continued

	Category of weight change										P-value
	Gained 10 kg or more	Gained 5–9.99 kg	Gained 2–4.99 kg	Gained 1–1.99 kg	Within 0.99 kg	Lost 1–1.99 kg	Lost 2–4.99 kg	Lost 5–9.99 kg	Lost 10 kg or more		
<b>ITALIAN/MALTESE</b>											
Overall % for Italian/Maltese men	3.0	15.7	26.6	12.4	19.0	7.1	11.0	3.9	1.3		
Age group (years)											
35–44 (n = 203)	5.9	23.6	33.5	10.8	15.3	3.4	5.9	1.0	0.5		<0.01
45–54 (n = 439)	3.0	18.5	32.1	12.3	15.9	6.2	8.4	2.7	0.9		
55–64 (n = 705)	3.0	13.2	24.5	12.6	21.1	7.4	12.2	4.4	1.6		
65 or over (n = 293)	1.4	11.9	18.4	13.3	21.2	10.2	15.4	6.5	1.7		
Education											
Primary (n = 785)	3.2	15.8	23.1	12.0	19.0	9.0	12.1	4.5	1.4		0.13
Some secondary (n = 452)	3.3	16.8	29.6	13.3	18.1	5.3	9.1	3.8	0.7		
Completed secondary (n = 253)	3.2	13.8	26.9	12.3	22.5	4.7	11.1	3.2	2.4		
Tertiary (n = 150)	1.3	14.7	35.3	12.7	16.0	6.0	10.7	2.7	0.7		
Baseline BMI category*											
Underweight† (n = 2)	50.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		<0.01
Healthy weight (n = 221)	4.5	23.1	34.8	13.6	15.8	3.6	3.2	0.9	0.5		
Overweight (n = 967)	2.9	15.6	27.0	12.7	20.8	7.0	10.2	2.8	0.9		
Obese (n = 450)	2.4	12.0	21.8	11.3	16.9	8.9	16.4	7.8	2.4		

\* Underweight – BMI < 20 kg m<sup>-2</sup>; healthy weight – BMI = 20–25 kg m<sup>-2</sup>; overweight – BMI > 25–30 kg m<sup>-2</sup>; obese – BMI > 30 kg m<sup>-2</sup>.

† Underweight was combined with healthy weight for analysis of variance owing to small numbers of underweight subjects.

**Table 4** Percentages of women in each category of weight change (kg) by age group, education, baseline category of body mass index (BMI) and ethnicity

	Category of weight change										P-value
	Gained 10kg or more					Lost					
	Gained 5-9.99kg	Gained 2-4.99kg	Gained 1-1.99kg	Within 0.99kg	Lost 1-1.99kg	Lost 2-4.99kg	Lost 5-9.99kg	Lost 10kg or more			
<b>Overall % for women in all three ethnic groups</b>	5.1	29.8	10.7	15.7	5.3	8.4	4.0	1.4			
<b>ANGLO-CELTIC</b>											
Overall % for Anglo-Celtic women	5.2	29.5	10.9	16.1	5.3	8.6	4.2	1.5			
Age group (years)											
35-44 (n = 2382)	7.3	29.8	10.5	14.5	3.6	7.0	2.8	0.9			<0.01
45-54 (n = 4400)	7.1	29.2	9.5	15.1	4.7	7.3	3.9	1.3			
55-64 (n = 4509)	3.9	30.1	12.2	16.1	5.7	9.2	4.3	1.7			
65 or over (n = 2200)	2.0	29.0	11.2	19.8	7.1	11.8	6.0	1.8			
Education											
Primary (n = 454)	5.3	26.7	11.0	15.2	5.1	10.4	5.3	2.0			0.17
Some secondary (n = 6703)	5.2	29.4	10.6	15.4	5.4	9.0	4.5	1.6			
Completed secondary (n = 2348)	5.5	29.2	11.1	17.1	5.4	8.3	4.4	1.4			
Tertiary (n = 3986)	5.1	30.4	11.3	16.8	5.0	8.0	3.3	1.2			
Baseline BMI category*											
Underweight† (n = 695)	4.0	38.6	14.4	17.8	2.4	2.6	0.4	0.1			<0.01
Healthy weight (n = 6553)	4.4	33.3	12.7	17.4	5.0	6.8	1.8	0.4			
Overweight (n = 4784)	5.4	26.4	9.7	16.0	6.0	10.5	5.7	1.1			
Obese (n = 2064)	7.7	21.6	7.2	12.0	5.4	12.2	9.6	6.1			
<b>GREEK</b>											
Overall % for Greek women	4.3	32.2	9.6	13.8	5.3	7.0	2.8	1.6			
Age group (years)											
35-44 (n = 199)	5.5	35.2	8.0	11.1	4.0	6.5	2.5	0.5			<0.01
45-54 (n = 659)	4.4	34.7	9.6	12.7	6.1	3.8	2.9	1.7			
55-64 (n = 599)	3.7	28.5	9.8	15.7	5.0	10.4	2.0	1.7			
65 or over (n = 99)	5.1	33.3	10.1	14.1	4.0	8.1	8.1	3.0			
Education											
Primary (n = 1180)	4.7	31.3	9.4	13.4	5.3	7.5	2.7	1.5			0.28
Some secondary (n = 225)	2.2	36.0	9.8	15.1	5.3	3.1	3.6	2.7			
Completed secondary (n = 115)	3.5	34.8	13.0	15.7	3.5	7.8	3.5	0.9			
Tertiary (n = 36)	8.3	36.1	0.0	11.1	11.1	11.1	0.0	0.0			
Baseline BMI category*											
Underweight† (n = 9)	11.1	33.3	22.2	11.1	0.0	0.0	0.0	0.0			<0.01
Healthy weight (n = 261)	5.7	36.4	11.1	12.3	4.6	3.8	1.1	0.0			
Overweight (n = 720)	3.9	24.7	8.8	13.2	4.6	6.0	1.5	0.4			
Obese (n = 601)	4.2	24.6	9.8	15.3	6.7	9.8	5.2	3.7			

Table 4. Continued

	Category of weight change										P-value
	Gained 10 kg or more	Gained 5–9.99 kg	Gained 2–4.99 kg	Gained 1–1.99 kg	Within 0.99 kg	Lost 1–1.99 kg	Lost 2–4.99 kg	Lost 5–9.99 kg	Lost 10 kg or more		
<b>ITALIAN/MALTESE</b>											
Overall % for Italian/Maltese women	5.2	22.1	30.5	10.3	14.0	5.4	7.9	3.9	0.9		
Age group (years)											
35–44 (n = 264)	8.7	25.4	31.8	9.8	11.4	2.7	7.2	2.7	0.4		<0.01
45–54 (n = 646)	5.3	26.5	29.3	10.1	14.4	4.3	5.7	3.6	0.9		
55–64 (n = 831)	4.1	19.4	31.9	9.9	13.7	7.3	8.8	4.2	0.7		
65 or over (n = 206)	3.9	16.0	27.7	12.6	18.0	4.9	11.2	3.9	1.9		
Education											
Primary (n = 1273)	5.1	21.0	29.8	10.5	14.2	6.4	7.7	4.2	1.1		0.20
Some secondary (n = 432)	5.3	25.2	31.0	7.6	14.8	3.5	8.3	3.7	0.5		
Completed secondary (n = 140)	6.4	21.4	31.4	15.7	12.1	4.3	6.4	2.1	0.0		
Tertiary (n = 102)	2.0	25.5	37.3	9.8	11.8	2.9	8.8	1.0	1.0		
Baseline BMI category*											
Underweight† (n = 20)	10.0	10.0	40.0	15.0	15.0	5.0	0.0	5.0	0.0		<0.01
Healthy weight (n = 424)	4.2	22.6	40.6	12.7	12.0	3.1	4.5	0.2	0.0		
Overweight (n = 807)	4.5	23.7	30.4	11.0	14.3	5.5	6.7	3.6	0.5		
Obese (n = 735)	6.4	20.3	24.5	7.9	14.8	6.8	11.3	6.3	1.8		

\* Underweight – BMI < 20 kg m<sup>-2</sup>; healthy weight – BMI = 20–25 kg m<sup>-2</sup>; overweight – BMI > 25–30 kg m<sup>-2</sup>; obese – BMI > 30 kg m<sup>-2</sup>.

† Underweight was combined with healthy weight for analysis of variance owing to small numbers of underweight subjects.



**Table 5** Percentages becoming overweight/obese by age group, education, baseline category of body mass index (BMI) and ethnicity among men

	Anglo-Celtic		Greek		Italian/Maltese	
	Overweight	Obese	Overweight	Obese	Overweight	Obese
Overall %	10.2	5.6	5.6	9.3	6.3	10.1
Age group (years)						
35–44	14.0*	6.4*	10.1**	10.1	9.4*	11.3
45–54	11.6	7.3	7.5	10.8	8.9	9.8
55–64	8.9	5.0	3.7	9.5	4.0	10.2
65 or over	6.7	3.0	4.7	5.2	6.1	9.6
Education						
Primary	8.3*	7.9*	5.3	9.9	5.0	10.6
Some secondary	9.3	6.3	5.1	10.2	6.9	10.6
Completed secondary	9.3	6.1	5.3	7.0	8.3	9.1
Tertiary	11.6	4.6	11.9	7.1	8.7	8.0
Baseline BMI category†						
Underweight	0.8*	0.0*	0.0***	0.0*	50.0	0.0*
Healthy weight	30.8	0.3	44.0	0.6	46.6	0.5
Overweight	NA	10.7	NA	15.8	NA	17.1

NA – already overweight at baseline; analyses compared underweight and healthy weight only.

\*,  $P < 0.01$ ; \*\*,  $P = 0.01$ ; \*\*\*,  $P = 0.05$ .

† Underweight – BMI  $< 20 \text{ kg m}^{-2}$ ; healthy weight – BMI =  $20\text{--}25 \text{ kg m}^{-2}$ ; overweight – BMI  $> 25\text{--}30 \text{ kg m}^{-2}$ ; obese – BMI  $> 30 \text{ kg m}^{-2}$ .

associated with obesity for Anglo-Celtic men only, with those aged 35–44 and 45–54 years more likely to become obese than older men. Among Anglo-Celtic men only, those who were tertiary-educated were more likely to become overweight, whereas those who were primary-educated were more likely to become obese. Similar trends with education were observed for Greek and Italian/Maltese men, although these did not reach significance. Men in a healthy weight range at baseline were more likely to become overweight, except for Italian/Maltese men. Similar patterns were found among women (Table 6). Younger women and tertiary-educated women were more likely to become overweight

regardless of ethnicity. Age was associated with becoming obese only among Anglo-Celtic women; those in mid-age groups (45–54 and 55–64 years) were at highest risk. Education was associated with risk of obesity only among Anglo-Celtic women, with primary-educated women most likely to become obese. Regardless of ethnicity, compared with other BMI categories, women in a healthy weight range at baseline were more likely to become overweight, and women who were overweight were more likely to become obese at follow-up.

Table 7 shows results of the multivariate regression models predicting weight change and risk of major weight gain for men and women, controlling for smoking status.

**Table 6** Percentages becoming overweight/obese by age group, education, baseline category of body mass index (BMI) and ethnicity among women

	Anglo-Celtic		Greek		Italian/Maltese	
	Overweight	Obese	Overweight	Obese	Overweight	Obese
Overall %	12.1	6.4	8.2	11.2	9.3	10.9
Age group (years)						
35–44	13.8*	5.8*	15.6*	9.5	13.3*	10.2
45–54	13.8	6.9	8.8	10.9	11.8	11.3
55–64	10.7	7.1	5.3	12.0	6.9	11.3
65 or over	9.8	5.0	7.1	11.1	6.3	9.2
Education						
Primary	8.4**	9.5*	6.9*	12.0	7.6*	11.8
Some secondary	11.7	7.3	11.1	8.9	12.3	9.5
Completed secondary	12.7	5.2	13.9	8.7	12.1	11.4
Tertiary	12.8	5.4	16.7	5.6	13.7	5.9
Baseline BMI category†						
Underweight	0.7*	0.0*	0.0*	0.0*	10.0*	0.0*
Healthy weight	25.9	0.9	49.8	1.1	43.2	0.7
Overweight	NA	17.6	NA	24.3	NA	26.4

NA – already overweight at baseline; analyses compared underweight and healthy weight only.

\*,  $P < 0.01$ ; \*\*,  $P < 0.05$ .

† Underweight – BMI  $< 20 \text{ kg m}^{-2}$ ; healthy weight – BMI =  $20\text{--}25 \text{ kg m}^{-2}$ ; overweight – BMI  $> 25\text{--}30 \text{ kg m}^{-2}$ ; obese – BMI  $> 30 \text{ kg m}^{-2}$ .

**Table 7** Multivariate regression models\* predicting weight change (linear regression) and risk of major (>5 kg) weight gain (logistic regression)

	Linear regression						Logistic regression					
	Males			Females			Males			Females		
	$\beta$	<i>t</i>	<i>P</i> -value	$\beta$	<i>t</i>	<i>P</i> -value	OR	95% CI	<i>P</i> -value	OR	95% CI	<i>P</i> -value
Age group (years)	-0.20	-21.93	<0.01	-0.13	-17.04	<0.01						
35–44							1.00			1.00		
45–54							0.68	0.60–0.77	<0.01	0.86	0.78–0.95	<0.01
55–64							0.40	0.35–0.46	<0.01	0.56	0.50–0.62	<0.01
65 or over							0.26	0.22–0.31	<0.01	0.34	0.30–0.39	<0.01
Education	-0.05	-5.13	<0.01	-0.05	-6.70	<0.01						
Primary							1.00			1.00		
Some secondary							0.81	0.70–0.94	<0.01	0.87	0.79–0.97	<0.05
Completed secondary							0.77	0.66–0.90	<0.01	0.79	0.70–0.90	<0.01
Tertiary							0.67	0.57–0.78	<0.01	0.76	0.68–0.86	<0.01
Baseline BMI category†	-0.17	-19.38	<0.01	-0.10	-13.06	<0.01						
Underweight or healthy							1.00			1.00		
Overweight							0.67	0.60–0.74	<0.01	1.20	1.11–1.30	<0.01
Obese							0.63	0.55–0.73	<0.01	1.18	1.07–1.31	<0.01

OR – odds ratio; CI – confidence interval; BMI – body mass index.

\* Both models adjusted for smoking status.

† Underweight – BMI < 20 kg m<sup>-2</sup>; healthy weight – BMI = 20–25 kg m<sup>-2</sup>; overweight – BMI > 25–30 kg m<sup>-2</sup>; obese – BMI > 30 kg m<sup>-2</sup>.

Owing to the similarities among ethnic groups in the results of bivariate analyses, data for the three groups were combined for multivariate analyses. The linear regression model showed that all three predictor variables (age group, education, baseline BMI category) significantly predicted weight change over time, with age group ( $\beta = -0.20$  for men,  $\beta = -0.13$  for women) and baseline BMI category ( $\beta = -0.17$  for men,  $\beta = -0.10$  for women) contributing the most. The models accounted for 7% of the variance in men's weight change and 3% in women's.

Results of the logistic regression showing adjusted odds ratios (ORs) for associations between the predictor variables and likelihood of major weight gain are also shown in Table 7. Among both men and women, higher age and higher education level were both associated with decreased likelihood of major weight gain. Among men, higher initial body weight was associated with decreased likelihood of major weight gain, whereas among women the reverse was true. Overweight and obese women were both about 20% more likely (OR = 1.20, 95% confidence interval (CI) 1.11–1.30 for overweight women; OR = 1.18, 95% CI 1.07–1.31 for obese women) to experience major weight gain compared with underweight or healthy weight women.

## Discussion

This study is one of the few to present data on the incidence of overweight and major weight change over time in a large community sample of adults, and the first to prospectively examine weight change patterns in men and women in the Australian population. The findings clearly demonstrate that, in this cohort, it was normal for adults to gain weight over time regardless of sex, age, educational

status, ethnicity or initial weight status. In this study relatively few individuals lost weight over the 5-year follow-up period, and maintenance of weight within 1 kg of initial weight occurred in fewer than one in five adults. The average weight gain per year in this Australian cohort was approximately 0.4 kg, which is generally consistent with the findings from other Western countries<sup>4,8,24</sup>. These findings support the broad thrust of Australia's national obesity strategy, which emphasises prevention of weight gain across the entire population<sup>22</sup>.

Certain population groups are at particularly high risk of weight gain. Consistent with previous research<sup>2,4,13</sup>, this study suggests young-to-mid adulthood may be a critical time to intervene to prevent weight gain. In this sample, those in the youngest age group, who were aged 35–44 years at baseline, experienced the largest average weight gain over the 5-year follow-up; they were more likely than older adults to experience a moderate to large weight gain (5 kg or more) and to become overweight. These findings in relation to weight gain, along with the fact that 50% of the 35–44-year-old adults were already overweight or obese at baseline, strongly suggest that obesity prevention efforts should focus on younger adults.

Results also demonstrate that young women and overweight/obese women are of particular concern in terms of weight gain. The youngest women in this sample experienced greater mean weight gain and higher risk of weight gain than any other group. Alarming, while overweight and obese women on average gained less weight than did other women, a moderate to large weight gain was the most common weight change pattern among those women already overweight or obese. Findings of multivariate analyses also showed that overweight and obese women had higher odds of major weight gain than

women in the healthy weight range or those who were underweight. These findings are consistent with those of NHANES I, which showed that women aged 25–44 years experienced the greatest average weight gain, that incidence of major weight gain in this age group was double that of older women, and that women of this age who were initially overweight had the highest incidence of major weight gain of any population subgroup<sup>2,4</sup>. The findings of the present study also support previous Australian research demonstrating that weight gain is common among women, particularly young women<sup>25</sup> and those already overweight<sup>26</sup>. The present data suggest that the emphasis on weight gain prevention for women aged 45–54 years in Australia's national obesity strategy, which identifies that group as being at risk of marked weight gain<sup>22</sup>, may require review. That recommendation was based on findings from cross-sectional data<sup>27</sup> that suggested a higher prevalence of overweight among this age group compared with younger age groups. In contrast, the findings of the present longitudinal study indicate that preventive efforts might be more effectively targeted towards younger women. Findings also suggest that women who are already overweight and obese comprise an important target group for public health interventions designed to prevent further weight gain.

We found complex relationships between education status and weight gain. Mean weight gain was not associated with education status except among Anglo-Celtic men, where the better educated gained the most weight. However, education was significantly associated with risk of becoming obese for Anglo-Celtic men and women, and with risk of becoming overweight for Anglo-Celtic men and for all women. The direction of these relationships differed, such that education was positively related to overweight risk but inversely related to obesity risk. A possible explanation for these findings is related to initial weight status. Less educated respondents in our sample were at baseline already more likely to be overweight at middle age than the more educated. Since the present results show that all respondents are generally continuing to gain weight through adult life, those less educated respondents, who were initially more likely to be overweight, would over the 5-year follow-up be likely to become obese; whereas those with more education who were initially more likely to be in the healthy weight range would be likely to have become overweight. This is not inconsistent with the results of the multivariate analysis showing that the less educated men and women were at highest risk of major weight gain, a finding that supports those of past studies<sup>16</sup>. Nonetheless, the complex associations between education, weight change, risk of major weight gain and overweight and obesity among men and women require further investigation.

While Greek respondents gained on average slightly more weight than did Italians or Anglo-Celts, overall we

found relatively few major differences in patterns of weight change by ethnicity. The similarities in weight change patterns between the three ethnic groups may be due to acculturation effects. A previous study of body weight and obesity among foreign-born women who had migrated to live in Australia showed that the longer the time since immigration, the higher the mean body weight and the greater the similarity between body weight of immigrants and Australian-born women<sup>28</sup>. As time since migration was not assessed in this study, it is not known to what extent this acculturation effect may have contributed to the present results. The similarity of findings across the three groups in this study suggests that the contributions of these sociodemographic predictors to weight change are not strongly influenced by ethnicity.

Several strengths of the present study lend support to the results. This is one of few studies to assess long-term weight change longitudinally in a large community sample of adults. The inclusion of large numbers of men and women from multiple countries of birth enabled comparisons of a range of sociodemographic predictors across groups. The prevalences of overweight and obesity at baseline were not dissimilar to those reported in existing cross-sectional studies of the Australian population<sup>27</sup>. However, it is important to acknowledge that these data, while drawn from a large cohort of adults living in Australia, are not necessarily representative of the entire Australian population. One limitation of the present study was that body weight was assessed objectively by researchers at baseline, but via self-report at follow-up. Use of self-reported weight data is likely to yield underestimates of the prevalence of overweight and obesity<sup>29</sup>. However, we applied an age- and gender-specific adjustment to follow-up body weight in order to counter possible self-report bias. The roles of behavioural factors known to impact on weight (e.g. physical activity and dietary intake) were also not investigated in these analyses, and are likely to be important additional predictors of adult weight change<sup>30</sup>. In longitudinal analyses such as those conducted in the present study, regression to the mean is a phenomenon that can impact on associations between initial values and change scores<sup>31</sup>. However, regression to the mean results mainly from errors in measurements. Hence it is unlikely to have had a major impact on results of the present study, since body weight is not highly prone to diurnal variability or reader or other measurement error, compared, for instance, with variables such as blood pressure.

Despite increasing prevalence of obesity world-wide, little is known about patterns of individual weight change within populations. These findings paint a bleak picture and highlight the need for public health efforts to reverse the obesity epidemic in Australia. Weight gain is a problem that is widespread in the adult population, affecting individuals of both sexes and all ages, and regardless of educational status, ethnicity or weight. However, while the

most common weight change observed in this cohort was weight gain, one in six adults were able to maintain their weight at its baseline level, and a small number did lose weight. It may thus prove useful to examine socio-demographic and behavioural characteristics of these individuals, in order to inform the development of effective population-wide strategies to prevent weight gain. However, the data presented here suggest that, without greater action, the epidemic of overweight and obesity, and thus the incidence of obesity-related disease, will continue to increase.

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