Projected socioeconomic disparities in the prevalence of obesity among Australian adults

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Abstract

Objective: To project prevalence of normal weight, overweight and obesity by educational attainment, assuming a continuation of the observed individual weight change in the 5-year follow-up of the national population survey, the Australian Diabetes, Obesity and Lifestyle study (AusDiab; 2000-2005).

Methods: Age-specific transition probabilities between BMI categories, estimated using logistic regression, were entered into education-level-specific, incidence-based, multi-state life tables. Assuming a continuation of the weight change observed in AusDiab, these life tables estimate the prevalence of normal weight, overweight and obesity for Australian adults with low (secondary), medium (diploma) and high (degree) levels of education between 2005 and 2025.

Results: The prevalence of obesity among individuals with secondary level educational attainment is estimated to increase from 23% in 2000 to 44% in 2025. Among individuals with a degree qualification or higher, it will increase from 14% to 30%. If all current educational inequalities in weight change could be eliminated, the projected difference in the prevalence of obesity by 2025 between the highest and lowest educated categories would only be reduced by half (to a 6 percentage point difference from 14 percentage points).

Conclusion: We predict that almost half of Australian adults with low educational status will be obese by 2025. Current trends in obesity have the potential to drive an increase in the absolute difference in obesity prevalence between educational categories in future years.

Implications: Unless obesity prevention and management strategies focus specifically on narrowing social inequalities in obesity, inequalities in health are likely to widen.

Key words: obesity, education, socio-economic status, projection, trend

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A socioeconomic patterning in the prevalence of obesity is observed in many developed nations. In general, when using education as an indicator of socioeconomic status (SES) an inverse relationship exists: higher educational attainment is associated with a lower prevalence of overweight and obesity.[1,2] Furthermore, weight gain over time is inversely associated with educational attainment.[3] In Australia, it is estimated that the prevalence of obesity in adults will increase from 20% in 2005 to 34% in 2025.[4] Similar projections have been estimated in other countries including the US[5] and UK.[6] Only two studies have attempted to predict the future prevalence of adult obesity by SES.[6,7] Forecasts of obesity prevalence in both these UK-based studies were derived using point prevalence estimates from multiple cross-sectional surveys. However, future inequalities in obesity prevalence are determined by both inequalities in obesity prevalence and inequalities in future weight gain. Although these studies address the former, they do not account for the latter.

Current obesity trends and their management have the potential to drive increased social inequalities in health; however, the implications of this have been largely neglected. We have little understanding of the likely magnitude of future social inequalities in obesity, or of what will be required to reduce the disparities in obesity prevalence. Without this information, policy aimed at decreasing social inequalities in obesity and its sequelae will continue to be neglected.

In these analyses, we estimate, for the first time, future inequalities in the prevalence of obesity in Australian adults according to educational attainment. We additionally

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estimate the effect of eliminating educational inequalities in weight change on the future inequalities of obesity prevalence. We do this using an incidence-based model, capturing transitions between BMI categories in a five-year follow-up of the Australian Diabetes, Obesity and Lifestyle (AusDiab) study between 2000 and 2005.

Methods

AusDiab data set

AusDiab is a national, population-based survey of 11,247 Australian adults aged ≥25 years at baseline (1999-2000) and has been described in detail previously.[8] Briefly, the response rate to the baseline biomedical testing among those who completed a household survey was 55%.[8] In 2004-05, all participants (n=11,247) were invited to a follow-up examination.[9]

For these analyses, participants who did not return to follow-up (n=4,847) or who were missing values for height or weight in 2000 or 2005, or missing data on educational attainment, were excluded (n=150). Due to small numbers of underweight participants (n=41), they were also excluded from the current analysis, leaving 10,994 participants at baseline and 6,250 at follow-up.

Mortality was determined by linkage to the National Death Index through to 1-6-2005. At both exams, measured height and weight were collected. BMI was categorised as normal weight (<24.9 kg/m^2), overweight (25.0-<30.0 kg/m^2) and obese (≥30.0 kg/m^2).[10,11]

Educational attainment was ascertained by asking "Which of these describes the highest qualification you have received?" and categorised in the current study as secondary only (comprising those with a secondary school qualification), diploma (comprising nursing or teaching qualification, trade or other certificate, associate or undergraduate diploma), and degree (comprising bachelor degree, post-graduate diploma or masters degree/doctorate). The study was approved by ethics committees of the International Diabetes Institute and Monash University. All participants provided informed consent.

Overview of the projection model

The overall approach to modelling the projected prevalence of obesity by SES is an extension of a previously published obesity projection model developed for the Australian adult population.[4] In brief, an abridged life table model was constructed between ages 25 and 85+ years, with the modelled states of normal weight, overweight, obesity, and dead. For participants in the AusDiab study, the age-specific odds of transitioning between each of the modelled states between 2000 and 2005 were estimated for each education category using logistic regression. The coefficients from this analysis were used to calculate transition probabilities, which were entered into education-specific multi-state life tables developed to project the future prevalence of normal weight, overweight and obesity to 2025.

Regression analyses

Transitions between BMI categories between the years 2000-2005 were modelled as binary variables. Logistic regression was used to estimate the odds of transitioning between BMI categories from baseline to follow-up according to educational attainment and five-year age category (or continuous age and age squared for mortality transitions). Pairwise interactions between education category and sex and age were tested for each transition, with no significant ($p<0.05$) interactions observed.

BMI transition probabilities

The future prevalence of normal weight, overweight and obesity was dependent on the age-specific probabilities of moving from one BMI category to another as observed in the AusDiab study between 2000 and 2005.[12] Five-year transition probabilities between adjacent BMI groups and mortality were estimated for each five-year age group and educational category using transition specific logistic regression (see below). A separate logistic regression analysis was used for each of the 10 transitions, each time comparing those making the transition of interest to all those not making the transition of interest from the starting category. In other words, all transitions probabilities from each baseline BMI category were estimated using the same group of participants. For example, all transition probabilities from overweight were estimated using all participants who were overweight at baseline. Separate logistic regression models were used to estimate each transition to normal weight, overweight, obese or dead at follow up with the remaining baseline overweight participants used as the comparator group each time. All transitions from each baseline BMI category summed to one. Very few people moved from normal weight to obese (one male, seven females) and obese to normal weight (one male, five females) over the five-year period, therefore only transitions to adjacent states were modelled. Age-specific probabilities for mortality were re-calibrated to reflect the mortality probabilities observed in the Australian population. This was done by apportioning the age-specific mortality probabilities from the Australian Bureau of Statistics[13] across the three BMI categories to reflect the distribution of mortality by BMI category in AusDiab. A Lowess smoother was applied to all transition probabilities between ages 25 and 85 years.[14] Age and education specific BMI transition probabilities that were used for the life table projections are available on request.

Life tables

The transition-based multi-state life table model used in this study has been described previously.[4] Briefly, abridged five-year period multi-state life-tables were constructed with four states (normal weight, overweight, obese and dead). The life table simulates the five-year progression of a cohort of 25-29-year-olds in 2000, exposed to the transition and mortality probabilities observed between 2000 and 2005, throughout their future lifetime, until death. A series of linked life tables were used to simulate the progress of the entire adult population each five years between the 2000 and 2025. Separate life tables were created to represent each of the three educational categories. For each education category, the baseline multi-state life-table population, representing the age structure in Australia in 2000 (according to the Australian Bureau of Statistics from national census data),[15] was created by first apportioning the age-specific total population numbers for 2000 into the three educational categories using the proportion of individuals in each category in the AusDiab study at baseline. This was then combined with the survey-weighted age-specific and education-specific prevalence of normal weight, overweight and obesity observed in the relevant education category in the AusDiab cohort for each five-year age group.

A new cohort of 25-29-year-olds entered the model every five years based on population projections between 2000 and 2025 from the Australian Bureau of Statistics.[15] It was assumed that the prevalence of normal weight, overweight and obesity at age 25-29 years changed to the same extent as that of those aged 30-34 years. From these projection models, age-specific and total prevalence of normal weight, overweight and obesity were derived for each education category, for each five-year period between 2000 and 2025.

Hypothetical scenario eliminating educational inequalities in transition probabilities

To explore the potential for eliminating future socioeconomic inequalities in the prevalence of obesity, we analysed whether assigning the lowest educational category the transition probabilities of those with the highest level of education would enable them to reach the same prevalence of normal weight as the highest education level group. Change was initiated from 2005 and flow-on effects on future prevalence of normal weight, overweight and obesity were estimated to 2025.

Table 1: Study population characteristics at baseline (1999/2000) and 5-year follow-up (2005)[a] from the Australian Diabetes, Obesity and Lifestyle Study.

	Secondary	Diploma	Degree	Total
		Baseline		
n (%)	4 500 (41%)	4 642 (42%)	1 852 (17%)	10 994
Mean age at baseline, years (SD)[b]	54.7 (15.0)	50.8 (13.9)	46.1 (11.9)	51.6 (14.4)
Sex (% males)[b]	34%	53%	52%	45%
Ethnicity (%)[b]				
Australia	78%	76%	71%	76%
UK/Northern Ireland	11%	11%	11%	11%
Rest of world	11%	18%	18%	13%
Smokers (%)[b]	18%	16%	9%	16%
Diabetes status (% with diabetes)[b]	11%	8%	5%	8%
BMI category[c]				
Normal weight (%)	1 568 (35.8%)	1 734 (37.6%)	831 (44.9%)	4 133 (37.59%)
Overweight (%)	1 763 (39.2%)	1 906 (41.1%)	739 (39.9%)	4 408 (40.1%)
Obese (%)	1 169 (25.98%)	1 002 (21.6%)	282 (15.23%)	2 453 (22.3%)
		Follow-up		
n (%)	2 327 (37%)	2 711 (43%)	1 212 (19%)	6 250
Mean age at baseline, years (SD)	55.4 (13.8)	52.2 (13.0)	47.5 (11.6)	52.6 (13.3)
Sex (% males)	34%	52%	53%	46%
Ethnicity (%)				
Australia	79%	76%	72%	76%
UK/Northern Ireland	11%	13%	11%	12%
Rest of world	10%	11%	17%	12%
Baseline number normal weight (%)	881 (35.0%)	1,067 (37.6%)	543 (43.9%)	2 491 (38.0%)
Baseline number overweight (%)	1 013 (40.3%)	1 166 (41.0%)	503 (40.7%)	2 682 (40.7%)
Baseline number obese (%)	618 (25.0%)	605 (21.3%)	190 (15.0%)	1 413 (21.4%)
Number of transitions of:				
Normal weight to normal weight (%)	629 (71.4%)	764 (71.6)	433 (79.7%)	1 826 (73.3%)
Normal weight to overweight (%)	184 (20.9%)	249 (23.3%)	98 (18.0%)	531 (21.3%)
Overweight to normal weight (%)	86 (7.8%)	65 (5.6%)	43 (8.6%)	194 (7.2%)
Overweight to overweight (%)	657 (59.6%)	864 (74.1%)	384 (76.3%)	1905 (71.0%)
Overweight to obese (%)	193 (17.5%)	186 (16.0%)	68 (13.5%)	447 (16.7%)
Obese to overweight (%)	59 (9.5%)	52 (8.6%)	14 (7.4%)	125 (8.8%)
Obese to obese (%)	519 (84.0%)	531 (87.8%)	172 (90.5%)	1222 (86.5%)
		Mortality		
Number of deaths in those:				
Normal weight at baseline (%)	68 (7.7%)	54 (5.1%)	12 (2.2%)	134 (5.4%)
Overweight at baseline(%)	77 (7.0%)	51 (4.4%)	8 (1.6%)	136 (5.5%)
Obese at baseline (%)	40 (6.5%)	22 (3.6%)	4 (2.1%)	66 (4.7%)

a The figures presented are crude numbers, unweighted for the sampling strategy of AusDiab
b Refers to a significant difference across education groups, p<0.05
c Defined according to BMI (kg/m2) cut offs: <25 (normal weight), 25-<30 (overweight), ≥30 (obese)

Sensitivity analyses

The projections in this paper are based on several assumptions which were tested in a number of sensitivity analyses. We tested the effect of 1) assigning nurses and teachers into the degree education category; 2) not using Lowess smoothing; 3) using only the significant BMI transition coefficients in combination with total population, non-education specific transition probabilities for non-significant transitions; and 4) adjusting for the potential confounders of smoking and alcohol.

We also tested the effect of the potential selection bias of the AusDiab cohort by imputing missing follow-up BMI data using multiple imputation. This process involved three distinct phases: 1) missing data were imputed 25 times; 2) multiple complete data sets were analysed using logistic regression in the same manner used for the complete case analysis; and 3) results from the imputed data sets were pooled according to Rubin's rules.[16,17] Covariates included in our imputation model included baseline BMI, age, education, systolic blood pressure, diastolic blood pressure, fasting plasma glucose, two-hour plasma glucose, triglycerides, language spoken at home, marital status, smoking status and vegetable consumption.

Results

Study population

All study population characteristics examined were significantly different across education groups (Table 1). Baseline prevalence of normal weight was highest in those with degree-level education and lowest in those with secondary education only. The prevalence of obesity was greatest in those with secondary education.

Odds of 5-year BMI gain

The five-year odds of remaining at normal weight was higher (OR 1.45 [95% CI 1.09 –1.92]) and the transition from normal weight to overweight was lower (OR 0.68 [95% CI 0.52–0.91]) in those with degree-level education compared to those with secondary education (Table 2). No differences in normal-weight transitions were seen in the diploma education category when compared to the secondary-education category. Those with a diploma or a degree, once overweight, were more likely to stay overweight after five-years than were those with secondary education only (OR 1.51 [95% CI 1.22–1.84] and OR 1.61 [95% CI 1.24–2.09], respectively). Accordingly, those with a diploma or a degree were less likely to transition from overweight to obese (OR 0.72 [95% CI 0.58–0.91] and OR 0.52 [95% CI 0.38–0.70]; Table 2) compared to those with secondary education.

Projected prevalence of normal weight, overweight and obesity

When projecting future trends in BMI groups, the prevalence of normal weight declined, overweight remained relatively stable or decreased slightly, and obesity increased in all three educational

Table 2: Age-adjusted odds ratios for transitioning between BMI categories between 1999/2000 & 2005 according to education category in 6,250 AusDiab participants.

	Secondary Ref	Diploma OR (95% CI)	Degree OR (95% CI)
Normal weight – normal weight[a]	1	0.95 (0.76-1.19)	1.45 (1.09-1.92)*
Normal weight – overweight[a]	1	1.04 (0.83-1.30)	0.68 (0.52-0.91)*
Normal weight – dead	1	1.27 (0.84-1.92)	1.27 (0.84-1.92)
Overweight – normal weight[a]	1	0.64 (0.45-0.90)*	1.04 (0.70-1.56)
Overweight – overweight[a]	1	1.51 (1.22-1.84)*	1.61 (1.24-2.09)*
Overweight – obese[a]	1	0.72 (0.58-0.91)*	0.52 (0.38-0.70)*
Overweight – dead	1	0.89 (0.60-1.27)	0.65 (0.30-1.40)
Obese – overweight[a]	1	0.87 (0.58-1.29)	0.69 (0.37-1.31)
Obese – obese[a]	1	1.15 (0.78-1.71)	1.44 (0.76-2.71)
Obese – dead	1	0.91 (0.52-1.58)	0.70 (0.23-2.05)

*$p<0.05$
a Refers to the odds of making the transition given that the individual is alive at follow-up.

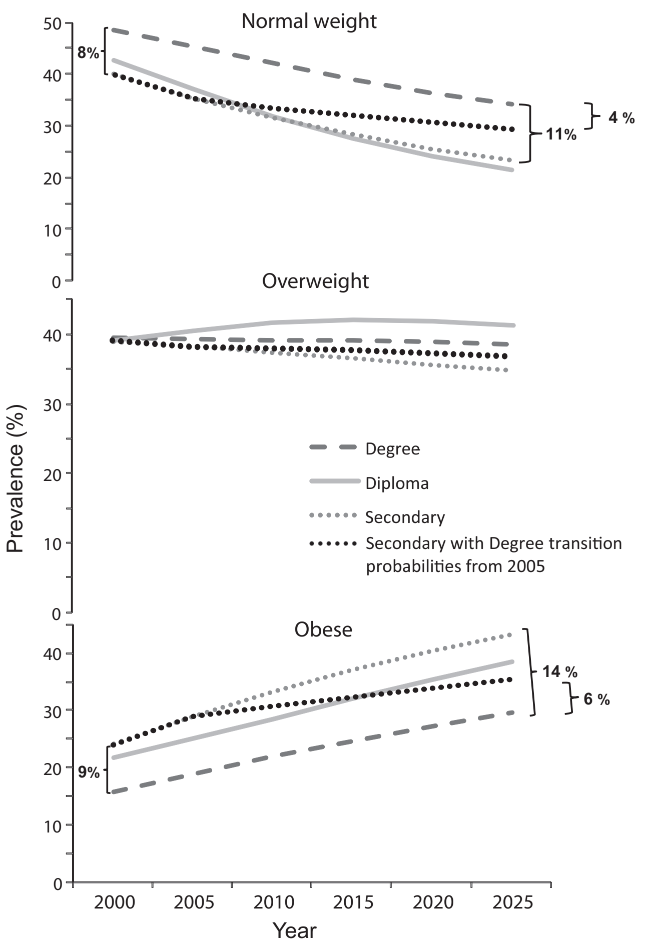
Table 3: Age-specific population prevalence of normal weight, overweight and obesity in 2000 and 2025.

BMI category	Age group (years)	Prevalence (%) Secondary 2000	Secondary 2025	Diploma 2000	Diploma 2025	Degree 2000	Degree 2025
Normal weight	25-44	44	23	49	22	53	35
	45-64	32	21	33	19	39	32
	65+	41	23	35	18	35	30
Overweight	25-44	36	33	34	39	36	36
	45-64	40	33	42	41	44	38
	65+	40	36	46	44	49	40
Obesity	25-44	20	44	17	39	12	30
	45-64	28	46	25	40	17	31
	65+	19	41	19	37	16	30

categories (Figure 1). The prevalence of normal weight, estimated at 47%, 41% and 39% in the year 2000, decreased to 33%, 20% and 22% in the year 2025 for degree, diploma and secondary level education categories respectively. All education categories started with a baseline prevalence of overweight at 39%, which did not change appreciably to 2025. The prevalence of obesity increased from 14%, 20% and 23% in the year 2000 to 30%, 39% and 44% in the year 2025 for degree, diploma, and secondary-level education categories respectively. The same patterns were observed in all age groups (Table 3).

The absolute difference in the prevalence of normal weight between degree-level and secondary education categories increased between 2000 and 2025 (Figure 1). At baseline, those with a degree had a prevalence of normal weight that was eight percentage points higher than in those with secondary education. By 2025 this difference had increased to 11 percentage points. The relative difference in normal weight prevalence between educational groups also increased over time, from a 17% higher prevalence of normal weight in the highest education category compared to the lowest education category in 2000 to a 33% higher prevalence in 2025.

Figure 1: Projected prevalence of normal weight, overweight and obesity according to educational attainment between 2000 and 2025 and the change in the projected prevalence for those in the lowest educated category if they experienced the transition probabilities of the highest educated category from 2005.



Note: Projections assume that incidence and mortality rates observed between 2000-2005 are held constant for the life of the cohort. Data is derived from the Australian Diabetes, Obesity and Lifestyle study (2000-2005)

The prevalence of obesity at baseline was nine percentage points lower in those with a degree compared to individuals with secondary education and by 2025 this had widened to 14 percentage points. The relative difference in obesity prevalence between educational groups decreased over time, from a 64% lower prevalence in the highest education category compared to the lowest education category in 2000 to a 47% difference in 2025.

Hypothetical scenario eliminating educational inequalities in transition probabilities

When the secondary-educated group were exposed to the transition probabilities of those in the highest education category from 2005, the projected prevalence of obesity in 2025 in the secondary-educated group was reduced from 44% in the original analysis to 35% (Figure 1). Consequently, the inequalities in obesity prevalence narrowed from 14 percentage points with current trends to 6 percentage points. The inequalities in the prevalence of normal weight also converged from a difference of 11 percentage points in the original analysis to a difference of 4 percentage points.

Sensitivity analyses

Projections based on each of the alternative assumptions in sensitivity analyses resulted in no substantial differences to either the overall projections or the disparities seen between all education categories by 2025.

Using the imputed data set, the projected 2025 prevalence of obesity and the predicted educational disparities were generally higher than when using the original dataset. The projected prevalence of obesity increased by 20 percentage points to 34% in the degree level, 27 percentage points to 47% in the diploma level and 31 percentage points to 54% in the secondary education categories between 2000 and 2025.

Discussion

Projecting recently observed individual-level rates of weight change and mortality, we demonstrate that the prevalence of obesity in the lowest educational category of Australian adults is likely to increase from 23% in 2000 to 44% in 2025. This equates to a nine percentage point greater prevalence of obesity in the lowest education group compared to the highest educated group in 2000 which increased to 14 percentage point difference in 2025. These disparities are evident across all age groups and represent a compound effect of both current inequalities in prevalence and continued inequalities in the rate of weight gain. We further illustrate the potential effect of eliminating all current educational inequalities in weight change and mortality. If this were feasible, the projected difference in the prevalence of obesity by 2025 between the highest and lowest educated categories could be reduced by half, although still not equalised.

This analysis predicts an increase in the absolute difference in the prevalence of both normal weight and obesity between educational categories. In contrast, it predicts an increase in the relative difference in the prevalence of normal weight between educational categories but a reduction in the relative difference in the prevalence of obesity. This apparent contradiction is a consequence of the higher baseline prevalence of obesity in the lowest education category and the mathematical ceilings by which such measures of inequality are bound.[18] Regardless, the increase in the absolute difference in obesity prevalence over the projected years has important implications for wider inequalities in health.

Our projections are based on observed educational inequalities in the development of overweight and obesity within a national population based cohort (AusDiab) between the years 2000 and 2005. Similar socioeconomic inequalities in weight gain have been observed in earlier studies from the USA,[19,20] Finland[21] and Australia.[22] However, never before have these rates been combined with rates of mortality and weight change to predict future inequalities in obesity prevalence. The socioeconomic patterning in weight gain that we observe herein is also akin to the well known social gradient in many other risk factors.[23] Nevertheless, obesity is one of the few risk factors that is increasing in prevalence,[24,25] and thus the implications for social inequalities in absolute terms is particularly important.

Two other studies, both from the UK, have estimated future socioeconomic inequalities in obesity prevalence, with conflicting results. The first, the Foresight report,[6] predicted that baseline disparities between five social classes would remain stable for men and women (with the exception of women from social class I) to 2050. The second study projected the prevalence of obesity to 2012, also by sex and social class; however in this study social class was dichotomised into manual and non-manual occupations.[7] An overall projected increase in the prevalence of obesity was noted, which was more pronounced in those from manual occupations. The reason for the discordance between the two studies despite the use of the same data is unclear. However, both studies are based on point prevalence estimates from multiple cross-sectional surveys, and do not reflect the effects of current socioeconomic inequalities in weight change.

One of the key strengths of our current model is that it is incidence-based, using the most recently available age-specific rates for transitioning between BMI categories. We are therefore able to capture the combined effect of inequalities in baseline prevalence, and continued inequalities in weight change. Other strengths include the short projected time frame (2005-2025); minimising the assumptions of the model, the use of measured height and weight, and accurate ascertainment of mortality.

The major limitation of our projections is the potential selection bias of the AusDiab study, with a 55% response rate at baseline, of whom 59% returned at follow-up. However, our overall estimate for the prevalence of obesity, overweight and normal weight in 2010 (27%, 39%, and 34%) was similar to those observed in the most recent (2007/08) National Health Survey in which 25% of Australians over 18 years of age were obese, 37% overweight, and 37% normal weight.[26] In addition, to address this limitation, we conducted multiple-imputation to estimate follow-up BMI for all individuals who did not return in 2005. Projecting BMI trends based on the imputed data-sets confirmed our result of increasing inequalities in the prevalence of obesity, albeit to a larger extent. This difference may reflect the fact that individuals who did not return to follow-up were both more likely to have lower educational attainment and to have higher BMI at baseline. Another potential limitation is that we did not stratify our results by sex. It is possible that inequalities in weight gain and thus, inequalities in the future population prevalence of obesity, differ for males and females. Although the interaction test between education and sex was not significant, it is possible that we did not have sufficient power to detect such an effect. A further limitation is that the observed educational inequalities relate to education levels attained since the 1950s. Rates of educational attainment have increased since then[27] and it is possible that this change in demographic composition of the educational groups may lead to different future educational inequalities in weight gain. Moreover, it is possible that education within persons may also change over time; however, formal education is commonly completed in early adulthood and is considered a relatively stable indicator of SES.[28] It is also of note that by only including one indicator of SES it is unlikely that we have captured all aspects of individual SES. However we choose education as an indicator of SES as it has been found to be consistently associated with obesity and weight gain[2,3] and is a strong determinant of other SES indicators such as future employment and income.[29] Finally, when interpreting results, it is important to consider that the estimated projections herein are based on the rate of weight change observed between 2000 and 2005, and do not reflect future potential changes in policy and practice. Additionally, it is possible that a proportion of the population may be protected from weight gain and thus will not follow the projected population body weight trajectory.

Our projections are based on directly observed relationships between education and weight change, and are not adjusted for potential confounders such as smoking and alcohol. This was to capture all observed lifestyle and demographic behaviours potentially contributing to the progression of BMI into the future. Alternative analyses controlling for smoking and alcohol yielded similar results.

There are a number of potential reasons for the increase in absolute socioeconomic differences in adult prevalence of obesity including differing environmental, social and cultural influences on lifestyle, and disparities in the uptake of health promotion and other public health interventions.[30,31] The increasingly higher prevalence of obesity in those with lower education levels illustrated in our study is likely to lead to increases in socioeconomic inequalities in health outcomes including diabetes, cardiovascular disease and osteoarthritis. Reducing socioeconomic differences in obesity prevalence will be critical to reduce future inequalities in the burden of chronic disease. We demonstrate in our analysis that if individuals from the lowest education category could attain the biologically feasible transition probabilities observed in the highest educated category, it would be possible to reduce disparities in obesity prevalence. However, prevention and treatment efforts need to include interventions specifically targeted towards lower SES groups if these inequalities are to be substantially reduced.

In conclusion, our results illustrate that current trends in obesity have the potential to drive continued socioeconomic inequalities in obesity prevalence among Australian adults. The challenge will be to implement interventions that not only curb current body weight trends within the population as a whole, but also narrow differences in obesity prevalence between socioeconomic groups.

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References

1. Wang Y, Beydoun MA. The obesity epidemic in the United States − gender, age, socioeconomic, racial/ethnic, and geographic characteristics: a systematic review and meta-regression analysis. *Epidemiol Rev*. 2007;29:6-28.
2. McLaren L. Socioeconomic status and obesity. *Epidemiol Rev*. 2007;29:29-48.
3. Ball K, Crawford D. Socioeconomic status and weight change in adults: a review. *Soc Sci Med*. 2005;60:1987-2010.
4. Walls HL, Magliano DJ, Stevenson CE, Backholer K, Mannan HR, Shaw JE, et al. Projected Progression of the Prevalence of Obesity in Australia. *Obesity (Silver Spring)*. 2011;20(4):872-8.
5. Stewart ST, Cutler DM, Rosen AB. Forecasting the effects of obesity and smoking on U.S. life expectancy. *N Engl J Med*. 2009;361:2252-60.
6. Government Office for Science UK. *Tackling Obesities: Future Choices − Modelling Future Trends in Obesity and their Impact on Health* [Internet]. London (UK): Department for Innovation, Universities and Skills; 2007 [cited 2010 Apr 1]. Available from: http://www.foresight.gov.uk/Obesity/14.pdf
7. Zaninotto P, Head J, Stamatakis E, Wardle H, Mindell J. Trends in obesity among adults in England from 1993 to 2004 by age and social class and projections of prevalence to 2012. *J Epidemiol Community Health*. 2009;63:140-6.
8. Dunstan DW, Zimmet PZ, Welborn TA, Cameron AJ, Shaw J, de Courten M, et al. The Australian Diabetes, Obesity and Lifestyle Study (AusDiab)--methods and response rates. *Diabetes Res Clin Pract*. 2002;57:119-29.
9. Magliano DJ, Shaw JE, Shortreed SM, Nusselder WJ, Liew D, Barr EL, et al. Lifetime risk and projected population prevalence of diabetes. *Diabetologia*. 2008;51:2179-86.
10. Regional Office for the Western Pacific Region of the World Health Organisation. *The Asia-Pacific Perspective: Redefining Obesity and its Treatment*. Sydney (AUST): Health Communications Australia; 2000.
11. World Health Organization. *Obesity: Preventing and Managing the Global Epidemic*. Geneva (CHE): WHO; 1998.
12. Backholer K, Walls HL, Magliano DJ, Peeters A. Setting population targets for measuring successful obesity prevention. *Am J Public Health*. 2010;100:2033-7.
13. Australian Institute of Health and Welfare. *Grim (General Record of Incidence of Mortality) Books* [Internet]. Version 8. Canberra (AUST): Commonwealth of Australia; 2005 [cited 2007 Jun 1]. Available from: *http://www.aihw.gov.au*
14. Cleveland W, Devlin S, Grosse E. Regression by local fitting. *J Econom*. 1988;37:87-114.
15. Australian Bureau of Statistics. *Population Projections, 2004-2101*. Canberra (AUST): ABS; 2006.
16. Little R, Rubin D. *Statistical Analysis With Missing Data*. Hoboken (NJ): Wiley; 2002.
17. Schafer J. *Analysis of Incomplete Multivariate Data*. London (UK): Chapman & Hall; 1997.
18. Houweling TA, Kunst AE, Huisman M, Mackenbach JP. Using relative and absolute measures for monitoring health inequalities: experiences from cross-national analyses on maternal and child health. *Int J Equity Health*. 2007;6:15.
19. Kahn HS, Williamson DF. Is race associated with weight change in US adults after adjustment for income, education, and marital factors? *Am J Clin Nutr*. 1991;53:1566S-70S.
20. Baltrus PT, Everson-Rose SA, Lynch JW, Raghunathan TE, Kaplan GA. Socioeconomic position in childhood and adulthood and weight gain over 34 years: the Alameda County Study. *Ann Epidemiol*. 2007;17:608-14.
21. Rissanen AM, Heliovaara M, Knekt P, Reunanen A, Aromaa A. Determinants of weight gain and overweight in adult Finns. *Eur J Clin Nutr*. 1991;45:419-30.
22. Ball K, Crawford D, Ireland P, Hodge A. Patterns and demographic predictors of 5-year weight change in a multi-ethnic cohort of men and women in Australia. *Public Health Nutr*. 2003;6:269-81.
23. Marmot M. Social determinants of health inequalities. *Lancet*. 2005;365: 1099-104.
24. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and Trends in Obesity Among US Adults, 1999-2008. *JAMA*. 2010;303(3):235-41.
25. Walls HL, Wolfe R, Haby MM, Magliano DJ, de Courten M, Reid CM, et al. Trends in BMI of urban Australian adults, 1980-2000. *Public Health Nutr*. 2010;13(5):631-8.
26. Australian Bureau of Statistics. *National Health Survey: Summary of Results, 2007-2008*. Canberra (AUST): ABS; 2009.
27. Australian Bureau of Statistics. *Australian Social Trends: Education Across Australia*. Canberra (AUST): ABS; 2008.
28. Galobardes B, Shaw M, Lawlor DA, Lynch JW, Davey Smith G. Indicators of socioeconomic position (part 1). *J Epidemiol Community Health*. 2006;60:7-12.
29. Lynch J, Kaplan GA. Socioeconomic position In: Berkman LF, Kawachi I, editors. *Social Epidemiology*. 1st ed. Oxford (UK): Oxford University Press; 2000.
30. Brennan SL, Henry MJ, Nicholson GC, Kotowicz MA, Pasco JA. Socioeconomic status and risk factors for obesity and metabolic disorders in a population-based sample of adult females. *Prev Med*. 2009;49:165-71.
31. Turrell G, Bentley R, Thomas LR, Jolley D, Subramanian S, Kavanagh AM. A multilevel study of area socio-economic status and food purchasing behaviour. *Public Health Nutr*. 2009;12:2074-83.