The case for action on socioeconomic differences in overweight and obesity among Australian adults: modelling the disease burden and healthcare costs

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Abstract

Objective: We aimed to quantify the extent to which socioeconomic differences in body mass index (BMI) drive avoidable deaths, incident disease cases and healthcare costs.

Methods: We used population attributable fractions to quantify the annual burden of disease attributable to socioeconomic differences in BMI for Australian adults aged 20 to <85 years in 2016, stratified by quintiles of an area-level indicator of socioeconomic disadvantage (SocioEconomic Index For Areas Indicator of Relative Socioeconomic Disadvantage; SEIFA) and BMI (normal weight, overweight, obese). We estimated direct healthcare costs using annual estimates per person per BMI category.

Results: We attributed $AU1.06 billion in direct healthcare costs to socioeconomic differences in BMI in 2016. The greatest number (proportion) of cases and deaths attributable to socioeconomic differences in BMI was observed for type 2 diabetes among women (8,602 total cases [16%], with 3,471 cases [22%] in the most disadvantaged quintile [SEIFA 1]) and all-cause mortality among men (2027 total deaths [4%], with 815 deaths [6%] in SEIFA 1).

Conclusions: Socioeconomic differences in BMI substantially contribute to avoidable deaths, disease cases and direct healthcare costs in Australia.

Implications for public health: Population-level policies to reduce socioeconomic differences in overweight and obesity must be identified and implemented.

Key words: socioeconomic factors, obesity, body mass index, epidemiology, epidemiological monitoring, costs and cost analysis

Overweight and obesity are important risk factors for a number of diseases that have a significant and increasing global burden.[1,2] These diseases include type 2 diabetes,[3] ischaemic heart disease,[4] cerebrovascular disease[5] and some cancers,[6] with risks increasing proportionate to body mass index (BMI).[7] Overweight and obesity are also notable risk factors for a range of other conditions including osteoarthritis[8] and depression,[9] and other risk factors with a significant global burden such as hypertension and high blood glucose.[1] Further, the healthcare costs of overweight and obesity are significant. The most recent estimates for Australia (2014–15) indicate that governments spend an additional $AU2.6 billion on healthcare costs each year due to obesity (BMI ≥ 30 kg·m^{-2}).[10]

In high-income countries, a higher prevalence of obesity is observed among those with greater socioeconomic disadvantage.[11] This socioeconomic gradient of obesity is likely to contribute to socioeconomic inequalities in morbidity and mortality.[12] In Australia, as elsewhere, greater socioeconomic disadvantage is also associated with a higher risk of a wide range of disease outcomes, including those associated with obesity as described above.[11,13] For example, Australian adults residing in areas of greatest socioeconomic disadvantage have a 1.8-fold higher rate of ischaemic heart disease mortality compared to their counterparts in areas of least socioeconomic disadvantage.[14]

One study has estimated the proportion of kidney cancer, colorectal cancer, breast cancer, diabetes mellitus, ischaemic heart disease, cerebrovascular disease and all-cause mortality attributable to educational differences in overweight and obesity for 21 European populations.[15] To our knowledge, how this translates to the absolute number of deaths and incident cases of disease, and the implications of this for direct healthcare costs, has never been quantified. Reducing the socioeconomic gradient in overweight and obesity will require concerted public health action to research and implement equitable prevention and treatment initiatives across the socioeconomic gradient. Understanding the burden of disease and healthcare costs attributable to socioeconomic differences in overweight and obesity, overall and for different socioeconomic groups will galvanise support for action.

The aim of this study was to estimate the annual burden of disease (through key disease outcomes and all-cause mortality)

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and direct healthcare costs attributable to the unequal distribution of overweight and obesity across the socioeconomic gradient for Australian adults in 2016.

Methods

Study design

To estimate the unequal distribution of overweight and obesity, we compared the 2016 prevalence of overweight and obesity for Australian women and men across quintiles of socioeconomic disadvantage (observed; data modelled from the 2014–15 National health Survey[16]) with the prevalence of overweight and obesity that would be expected to occur if all quintiles of socioeconomic disadvantage had the same prevalence of overweight and obesity as the women and men in the least disadvantaged quintile (counterfactual). Comparing this observed and counterfactual prevalence of overweight and obesity allows us to estimate the disease burden and direct healthcare costs attributable to the unequal distribution of overweight and obesity for Australian women and men.

We used the SocioEconomic Index for Areas (SEIFA), 'index of relative socioeconomic disadvantage' to indicate the level of socioeconomic disadvantage. SEIFA is an ordinal, area-based indicator of socioeconomic position that reflects the average socioeconomic characteristics of residents within each of the 54,805 statistical geographic areas in Australia (each containing approximately 400 individuals) based on Census information,[17] and ranks them from most to least disadvantaged. We used quintiles of SEIFA, whereby SEIFA 1 represents residents living in areas with greatest socioeconomic disadvantage, and SEIFA 5 represents residents living in areas with least socioeconomic disadvantage.

To estimate the annual disease burden, we selected eight key obesity-related disease outcomes – outcomes that were both strongly associated with obesity[18] and represent a significant global burden.[2] This included three cardio-metabolic diseases: type 2 diabetes, ischaemic heart disease and cerebrovascular disease; four cancers: colorectal cancer, kidney cancer, endometrial cancer and post-menopausal breast cancer; and all-cause mortality. Where Australian data were available, we examined both incidence (number of cases) and mortality (number of deaths) for each disease outcome (Supplementary Tables 1 and 2).

All disease inputs were sex-specific and derived for Australian adult women and men aged 20 to <85 years (or women 50 to <85 years for post-menopausal breast cancer) according to quintiles of SEIFA. We used the most recently available Australian data for each input (which ranged from 2000–2012 to 2016; Supplementary Table 1) and weighted all estimates to the 2016 population size of women and men aged 20 to 84 years.[19] As Australian data for most inputs were not available disaggregated by SEIFA for the 20 to 84 years age group, multiple data sources were combined to estimate the age- and SEIFA-specific input data for this analysis (Supplementary Table 2). A detailed description of how datasets were combined for each input is described in Supplementary File A.

To calculate the population attributable fractions (PAFs; described below), we used a sex-specific relative risk, rate ratio or hazard ratio (RR) for the relationship between overweight and obesity and each disease outcome, relative to normal weight, from the most contemporary, or most comprehensive, meta-analysis of cohort studies, or pooled cohort analysis (Supplementary Table 3). In line with previous research,[2] where possible we used RRs that were adjusted for key confounders (including age, sex, smoking status) and did not adjust for factors likely to lie within the causal pathway between obesity and the disease (such as diet and physical activity). We use the same RRs for all SEIFA quintiles, thereby assuming that SEIFA does not moderate the relationship between obesity and disease outcomes (this assumption has been empirically validated in a prior Australian study for type 2 diabetes).[20]

Analyses

As per Hoffman et al.[21] we used sex-specific population attributable fractions (PAF) to estimate the proportion of deaths and incident cases attributable to the unequal distribution of normal weight (NW) overweight (OW) and obesity (Ob): $PAF = [(RR_{Ob*}\%Ob_{observed} + RR_{OW}*\%OW_{observed} + 1*\%NW_{observed}) - (RR_{Ob*}\%Ob_{counterfactual} + RR_{OW}*\%OW_{counterfactual} + 1*\%NW_{counterfactual})]/(RR_{Ob*}\%Ob_{observed} + RR_{OW}*\%OW_{observed} + 1*\%NW_{observed})$. We calculated an estimate range of the PAF for each disease outcome by repeating the calculation using the upper and lower 95%CI estimates of the RR. For each disease outcome, we multiplied the PAF by the observed number of deaths and incident cases to estimate the annual number of deaths and cases potentially attributable to the unequal distribution of overweight and obesity.

We used a relative concentration index (RCI) and absolute concentration index (ACI) to assess the overall magnitude of relative inequality and absolute inequality for each disease outcome attributable to the unequal distribution of overweight and obesity. Here, negative RCI and ACI values indicate a disproportionate share of each disease outcome among those with greater socioeconomic disadvantage, a value of 0 for the RCI and ACI indicates no inequality, and positive RCI and ACI values indicate a disproportionate share of each disease outcome among those with lesser socioeconomic disadvantage.

To estimate the direct healthcare costs attributable to the unequal distribution of overweight and obesity across the socioeconomic gradient, we used previously derived estimates of the annual direct healthcare costs per person from a cohort of Australian adults that was broadly representative of the Australian population.[31] These estimates were applied to the average observed and counterfactual prevalence of normal weight, overweight and obesity for Australian women and men aged 20 to 84 years in 2016. Costs were inflated from 2005 to 2016 Australian dollars using historical Health Price indices and linear trend estimation.[22]

All analyses were sex-specific and conducted for Australian adults aged 20 to 84 years in 2016 (or 50 to 84 years for post-menopausal breast cancer). Input data[16,19-44] is described in full in Supplementary File A and Supplementary Tables 1, 2 and 3. The statistical methodology is described in detail in Supplementary File B.

Ethics statement

Ethics approval for the current study was obtained through the Monash University Human Research Ethics Committee; CF15/21 – 2015000018, and through Deakin University Human Research Ethics Committee; 2016-0141.

Results

SEIFA-patterning of normal weight, overweight and obesity

For women, we observed a socioeconomic gradient in the prevalence of obesity and normal weight across SEIFA quintiles. Compared to women with greatest

socioeconomic disadvantage (SEIFA 1), women with least socioeconomic disadvantage (SEIFA 5) had a 14%-point higher prevalence of normal weight, and a 12%-point lower prevalence of obesity (Figure 1, Supplementary Table 4). We did not observe a socioeconomic gradient in the prevalence of overweight, which varied by up to 4%-points across all SEIFA quintiles.

For men, we observed a socioeconomic gradient in the prevalence of obesity, overweight and normal weight. Compared to men with greatest socioeconomic disadvantage (SEIFA 1), men with least socioeconomic disadvantage (SEIFA 5) had a 5%-point higher prevalence of normal weight, a 8%-point higher prevalence of overweight, and a 13%-point lower prevalence of obesity (Figure 1, Supplementary Table 4).

SEIFA-patterning of each disease outcome

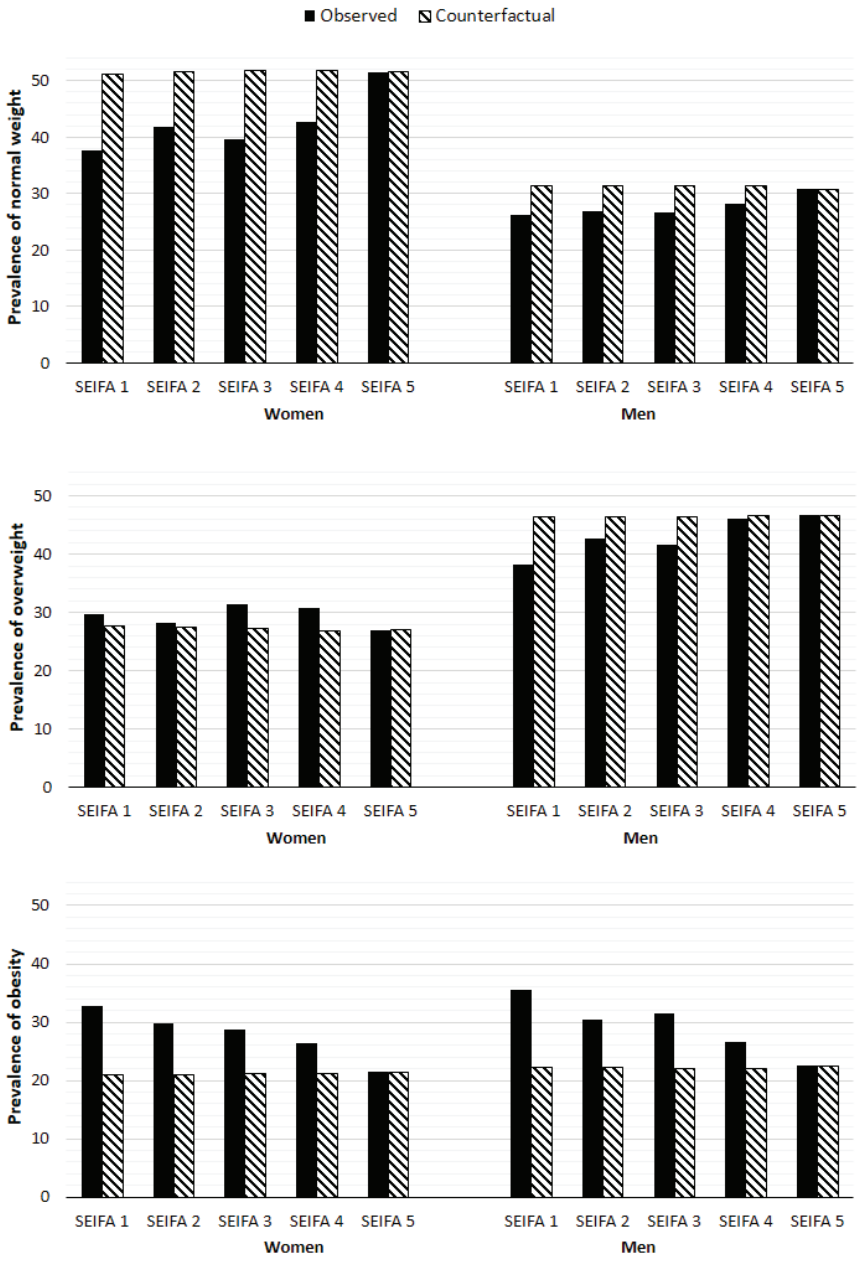
With the exception of incident post-menopausal breast cancer, those with greater socioeconomic disadvantage had higher rates of each disease and all-cause mortality compared to their counterparts with lesser disadvantage (Table 1). This was reflected by a negative RCI and ACI (Figure 2). The socioeconomic patterning of post-menopausal breast cancer was not clear. The highest incidence was observed for women with second greatest socioeconomic disadvantage (SEIFA 2), followed by women with least socioeconomic disadvantage (SEIFA 5), and then women with greatest socioeconomic disadvantage (SEIFA 1). This was reflected by an observed RCI of -0.006.

The RCI and ACI for all outcomes was improved under the counterfactual distribution of overweight and obesity (values were closer to 0, indicating less inequality), but remained negative (indicating a disproportionate share of disease among those with greater socioeconomic disadvantage); see Figure 2.

Disease burden attributable to the unequal distribution of overweight and obesity

We present in Table 2, for each SEIFA quintile and all quintiles together, the proportion of each disease outcome potentially attributable to differences in the prevalence of overweight and obesity across the socioeconomic gradient (PAF), as well as the estimated number of cases or deaths this equates to.

Figure 1. Age-standardised observed and counterfactual prevalence of normal weight, overweight and obesity for Australian women and men aged 20 to 84 years in 2016.



Notes:

All estimates were age-standardised to the SEIFA-specific 2016 population using the direct method; NW, Normal weight (BMI<25 kg m-2); OW, Overweight (BMI≥25 kg m-2 and <30 kg m-2); OB, Obese (BMI≥30 kg m-2); W, Women; M, Men; SEIFA, Socioeconomic index for areas, 'index of relative socioeconomic disadvantage', where SEIFA 1 represents residents of areas with greatest socioeconomic disadvantage, and SEIFA 5 represents residents of areas with least socioeconomic disadvantage; The counterfactual distribution reflects the prevalence of normal weight, overweight and obesity that would be expected to occur if all SEIFA quintiles had the same prevalence of normal weight, overweight and obesity as the women and men in the least disadvantaged quintile.

The greatest number of incident cases attributable to socioeconomic differences in BMI was observed for type 2 diabetes among women (8,602 cases [16%]), with 3,471 cases [22%] in the most disadvantaged quintile [SEIFA 1]). The greatest number of deaths attributable to socioeconomic differences in BMI was observed for all-cause mortality among men (2,027 deaths [4%], with 815 deaths [6%] in SEIFA 1).

In total: 16,281 cases of type 2 diabetes, colorectal cancer, kidney cancer, endometrial cancer and post-menopausal breast cancer; 3,562 deaths from all-cause mortality; and 596 deaths from ischaemic heart disease, cerebrovascular disease, colorectal cancer, kidney cancer, endometrial cancer and post-menopausal breast cancer could be attributed to the socioeconomic gradient in overweight and obesity among Australian

women and men in 2016. Further, we found that the socioeconomic gradient in overweight and obesity contributes to the relative and absolute inequalities for each disease outcome, as indicated through the RCI and ACI.

Direct healthcare costs attributable to the unequal distribution of overweight and obesity

The estimated annual direct healthcare cost per person for women and men aged 20 to 84 years with normal weight, overweight and obesity in 2016 was AU$1,706 ($1,488, $1,926), $2,026 ($1,842, $2,210) and $2,634 ($2,389, $2,878), respectively. These costs modelled across the 2016 Australian population equated to $18,325.2 million for women and $18,431.2 million for men.

We found that an estimated $636.5 million ($628.2, $644.0) and $421.7 million ($395.5, $447.2) in direct healthcare spending for women and men aged 20 to 84 years in 2016 – $1.06 billion ($1.02, 1.09) in total – was potentially attributable to the socioeconomic gradient in overweight and obesity. Hence, approximately 3.4% and 2.5% of modelled direct healthcare spending for women and men could be attributed to the socioeconomic gradient in overweight and obesity.

Discussion

Key results

This was the first study to estimate the direct healthcare costs associated with the unequal distribution of overweight and obesity across the socioeconomic spectrum. An estimated $1.06 billion (95%CI $1.02, 1.09) in direct healthcare costs can be attributed to the socioeconomic gradient in overweight and obesity among Australian women and men in 2016, which is approximately 2.9% of total spending.

Literature comparison

Our results for the lowest SEIFA quintile are comparable with results for the lowest education group from a previous study that used a PAF model to calculate the burden of educational differences in the prevalence of overweight and obesity on mortality from three cancers (kidney and renal pelvis cancer, post-menopausal breast cancer and colorectal cancer), three cardio-metabolic diseases (ischaemic heart disease, cerebrovascular disease and diabetes mellitus), and all-cause mortality across 21 European countries.[15] Across the two studies, PAF estimates for women differ by up to 1.5%-points, and PAF estimates for men differ by up to 3%-points.

Australia is not unique in having both a high prevalence of overweight and obesity and a steep socioeconomic gradient in both overweight and obesity and disease outcomes of interest. As demonstrated through the similarity of our PAF estimates and a prior study,[15] the proportion of the disease burden described for Australian adults may be comparable to the proportion of the disease burden for other high-income countries.

We are the first to estimate the direct healthcare costs that can be attributed to the unequal distribution of overweight and obesity across socioeconomic groups. Our findings support previous studies that have demonstrated a significant potential economic benefit to reducing racial inequalities in disability, illness and premature mortality in the US,[45] health inequalities by income level in Canada[46] and general socioeconomic inequalities in the UK.[47]

Strengths and limitations

The first strength of this study is our use of a robust and systematic approach[21] to model the disease burden associated with the unequal distribution of overweight and obesity across the socioeconomic spectrum. We examine both all-cause mortality and key disease outcomes with a high burden. Additionally, we examine both the proportion and absolute number of deaths and cases of key diseases and all-cause mortality that can be attributed to the socioeconomic gradient in overweight and obesity.

Secondly, the data for our model inputs included measured height and weight and ICD-10 coded disease outcomes. Further, unlike previous studies, we model incident type 2 diabetes, which is more strongly associated with overweight and obesity than diabetes mellitus (a combined estimate of type 1 and type 2 diabetes). This ensures our

Table 1. Observed number of deaths and incident cases of disease for Australian adults aged 20 to 84 years in 2016.

		SEIFA 1	SEIFA 2	SEIFA 3	SEIFA 4	SEIFA 5
		N	N	N	N	N
All-cause mortality						
W		9,212	8,910	7,639	6,600	6,261
M		13,737	12,966	11,250	11,189	8,122
Incident type 2 diabetes						
W		15,961	10,784	12,499	8,910	7,049
M		18,791	15,839	10,601	12,301	12,093
Ischaemic heart disease mortality						
W		778	751	633	539	507
M		1,858	1,712	1,477	1,158	1,019
Cerebrovascular disease mortality						
W		537	543	460	400	420
M		590	563	492	398	388
Colorectal cancer incidence and mortality						
W	I	1,249	1,275	1,142	1,107	1,070
W	M	304	295	266	242	232
M	I	1,677	1,712	1,554	1,388	1,314
M	M	449	424	401	332	307
Kidney cancer incidence and mortality						
M	I	407	434	396	356	341
	M	112	114	104	80	73
Endometrial cancer incidence and morality						
W	I	512	533	486	468	434
	M	87	93	88	75	69
Post-menopausal breast cancer incidence and mortality (Aged 50 to <85 years)						
W	I	2,649	2,757	2,544	2459	2,703
	M	482	456	410	357	368

Notes:
SEIFA, Socioeconomic index for areas, 'index of relative socioeconomic disadvantage'
W: women;
M: men

model is robust and allows for a more precise estimation of the disease burden associated with overweight and obesity.

Finally, we derived RRs from the most recent and/or most comprehensive meta-analysis or pooled cohort study. Studies included 15,700 to 264,400 events, and most estimates were 'adequately adjusted' (adjusted for age, sex and smoking status only, and not variables on the causal pathway). Estimates for type 2 diabetes,[3] colorectal cancer,[28] kidney cancer,[29] endometrial cancer[30] and post-menopausal breast cancer[31] incidence and mortality were derived from meta-analyses, which included studies with different levels of adjustment. These ranged from minimally adjusted studies that controlled for age and sex only, through to studies that were adjusted for a wider suite of potential confounders. While adjusting for a wide suite of confounders may result in an underestimated RR,[27] the impact of including such studies on the final estimate was minimal for the kidney cancer[29] and colorectal cancer[28] estimates.

The first limitation of our study is that the model relies on historic data inputs – including the number of deaths and incident cases of disease, the prevalence of overweight and obesity, and the relationship between overweight and obesity with disease outcomes. Additionally, the model links the estimated 2016 overweight and obesity exposure levels to estimated 2016 deaths and incident cases of disease. Consequently, our model will be affected by time trends in both overweight and obesity and all disease outcomes of interest. As the rate of change in obesity, disease and mortality trends over the period of input data collection to 2016 is likely to be small, any such differences are likely to minimally affect modelled estimates.

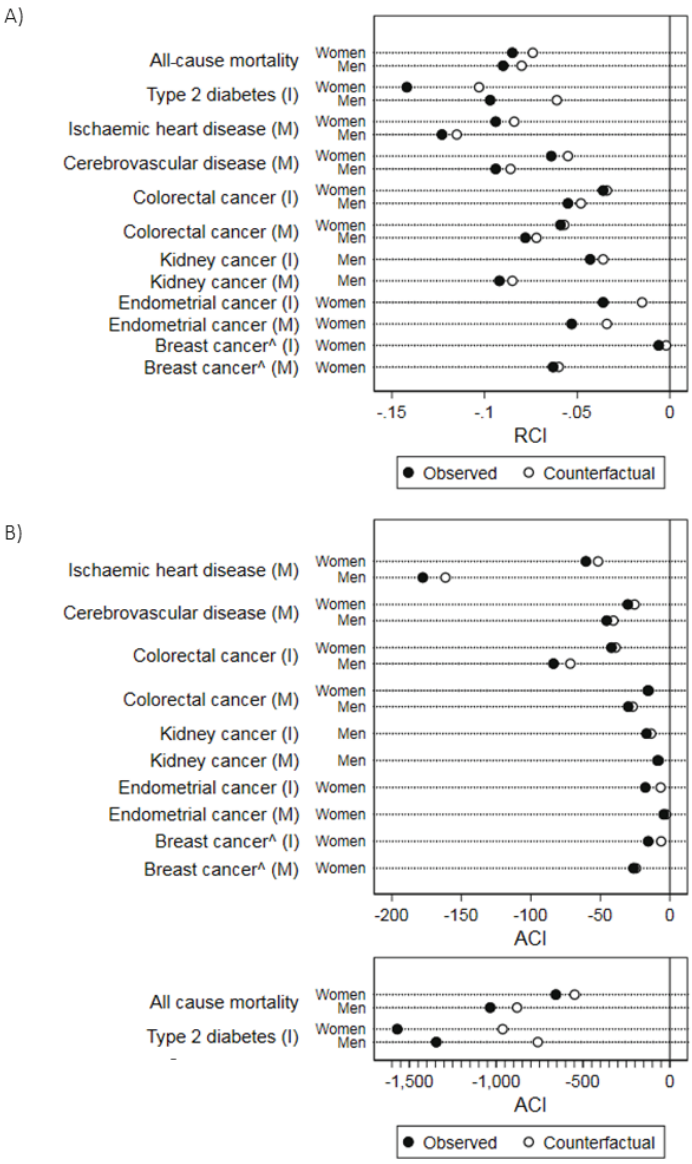
Secondly, we apply the SEIFA-patterning of all disease outcomes and all-cause mortality for the total population to our analytic population of 20–84-year-olds. As most outcomes occur in this age group, the effect of this assumption is likely to be minimal.

Thirdly, we included individuals with underweight (BMI <18.5 kgm^{-2}) in the normal weight group, despite their increased risk of ill-health relative to normal weight. This was for two reasons: 1) the prevalence of underweight within the 2014 National Health Survey was too low (1.9% and 0.8% for women and men, respectively) to estimate the prevalence of underweight across SEIFA quintiles; 2) including individuals with underweight in the normal weight category (rather than excluding them from analyses) ensured that the total number of individuals modelled remained constant across the observed and counterfactual scenarios. As the prevalence of underweight is so low, the effect of their inclusion in the normal weight category is likely to be minimal.

Fourthly, our endometrial cancer incidence and prevalence data was calculated as 95% of all uterine cancers.[25] This assumption does not affect the endometrial cancer PAF estimate or estimated total number of cases and deaths for the total population, but the number of cases and deaths for each SEIFA quintile, and the modelled RCI and ACI, may be affected.

Fifthly, while all RRs used were from the most recently available or most comprehensive meta-analysis or multi-cohort study (as described above), they remain an estimation of what we would expect to see in our analytic population of Australian adults aged 20 to 84 years. A number of factors contribute to potential variation from an RR.

Figure 2: Relative and absolute concentration indices associated with the observed and counterfactual distributions of all disease outcomes for women and men.



Notes:

RCI: Relative Concentration Index; ACI: Absolute Concentration Index; I: Incidence; M: Mortality;

A) Relative concentration index associated with the observed and counterfactual distributions of all disease outcomes.

B) Absolute concentration index associated with the observed and counterfactual distributions of all disease outcomes.

Figure 2B is presented across two panels to account for the differing scale of the ACI for all-cause mortality and type 2 diabetes compared to all other disease outcomes.

Table 2: Proportion and number of cases and deaths for specific obesity sequelae attributable to socioeconomic differences in BMI according to SEIFA for Australian women and men aged 20 to 84.

		SEIFA 1	SEIFA 2	SEIFA 3	SEIFA 4	Total*
		% or # (estimate range)	% or # (estimate range)	% or # (estimate range)	% or # (estimate range)	% or # (estimate range)
All-cause mortality						
W&M	%	6 (6, 6)	4 (4, 4)	4 (4, 5)	2 (2, 2)	4 (4, 4)
	# I	1,387 (1,340, 1,444)	934 (901, 972)	834 (804, 867)	408 (392, 423)	3,562 (3,436, 3,706)
W	%	6 (6, 6)	5 (5, 5)	4 (4, 5)	3 (3, 3)	4 (4, 4)
	# I	572 (550, 593)	419 (403, 435)	337 (323, 349)	207 (198, 215)	1,535 (1,474, 1,592)
M	%	6 (6, 6)	4 (4, 4)	4 (4, 5)	2 (2, 2)	4 (3, 4)
	# I	815 (790, 850)	515 (498, 537)	497 (481, 518)	201 (193, 209)	2,027 (1,962, 2,115)
Incident type 2 diabetes						
W&M	%	19 (17, 20)	14 (13, 15)	15 (14, 16)	9 (8, 10)	13 (11, 13)
	# I	6,573 (6,012, 6,993)	3,700 (3,367, 3,955)	3,510 (3,149, 3,779)	1,867 (1,652, 2,029)	15,650 (14,179, 16,756)
W	%	22 (19, 24)	17 (15, 19)	17 (15, 19)	13 (11, 14)	16 (13, 17)
	# I	3,471 (3,025, 3,802)	1,832 (1,586, 2,018)	2,145 (1,843, 2,367)	1,154 (982, 1,281)	8,602 (7,437, 9,468)
M	%	17 (16, 17)	12 (11, 12)	13 (12, 13)	6 (5, 6)	10 (10, 10)
	# I	3,102 (2,986, 3,191)	1,868 (1,781, 1,937)	1,365 (1,306, 1,412)	713 (670, 748)	7,048 (6,742, 7,288)
Ischaemic heart disease mortality						
W&M	%	5 (4, 6)	4 (3, 4)	4 (3, 5)	2 (2, 3)	3 (2, 4)
	# D	131 (103, 159)	88 (67, 108)	80 (61, 98)	35 (25, 45)	333 (257, 409)
W	%	6 (4, 8)	4 (3, 6)	4 (3, 6)	3 (2, 4)	4 (3, 5)
	# D	47 (33, 59)	34 (24, 43)	28 (20, 37)	17 (12, 23)	126 (88, 162)
M	%	5 (4, 5)	3 (3, 4)	3 (3, 4)	2 (1, 2)	3 (2, 3)
	# D	84 (70, 99)	54 (44, 65)	51 (42, 61)	18 (14, 22)	207 (169, 247)
Cerebrovascular disease mortality						
W&M	%	5 (4, 5)	3 (3, 4)	3 (3, 4)	2 (2, 2)	3 (2, 3)
	# D	51 (41, 60)	36 (29, 43)	32 (26, 38)	15 (12, 19)	134 (108, 160)
W	%	5 (4, 6)	4 (3, 4)	4 (3, 4)	3 (2, 3)	3 (2, 4)
	# D	26 (21, 31)	20 (16, 24)	16 (13, 20)	10 (8, 12)	72 (57, 87)
M	%	4 (4, 5)	3 (2, 3)	3 (3, 4)	1 (1, 2)	3 (2, 3)
	# D	25 (21, 29)	16 (13, 19)	16 (13, 18)	5 (4, 6)	62 (51, 73)
Colorectal cancer incidence and mortality						
W&M	%	3 (2, 3)	2 (1, 2)	2 (1, 3)	1 (1, 1)	2 (1, 2)
	# I	79 (57, 99)	57 (40, 74)	56 (39, 72)	26 (15, 36)	219 (150, 281)
	# D	21 (15, 26)	14 (10, 18)	14 (10, 18)	6 (4, 8)	55 (38, 70)
W	%	1 (0, 2)	1 (0, 2)	1 (0, 2)	1 (0, 1)	1 (0, 1)
	# I	16 (4, 29)	12 (3, 22)	12 (2, 21)	8 (1, 15)	48 (11, 87)
	# D	4 (1, 7)	3 (1, 5)	3 (0, 5)	2 (0, 3)	11 (3, 20)
M	%	4 (3, 4)	3 (2, 3)	3 (2, 3)	1 (1, 2)	2 (2, 3)
	# I	63 (53, 70)	45 (36, 52)	45 (37, 51)	18 (14, 21)	170 (139, 195)
	# D	17 (14, 19)	11 (9, 13)	12 (9, 13)	4 (3, 5)	44 (36, 50)
Kidney cancer incidence and mortality						
M	%	4 (3, 6)	3 (2, 4)	3 (2, 4)	1 (1, 2)	2 (2, 3)
	# I	17 (12, 23)	13 (9, 17)	13 (9, 17)	5 (3, 7)	47 (33, 64)
	# D	5 (3, 6)	3 (2, 5)	3 (2, 5)	1 (1, 2)	12 (9, 17)
Endometrial cancer incidence and morality						
W	%	12 (10, 13)	9 (8, 10)	9 (7, 10)	6 (5, 7)	7 (6, 8)
	# I	60 (53, 65)	48 (42, 52)	42 (36, 46)	29 (25, 33)	178 (156, 196)
	# D	12 (10, 13)	9 (8, 10)	9 (7, 10)	6 (5, 7)	7 (7, 8)
Post-menopausal breast cancer incidence and mortality (Aged 50 to <85 years)						
W	%	2 (1, 3)	2 (1, 2)	2 (1, 3)	2 (1, 2)	1 (1, 2)
	# I	57 (30, 85)	43 (22, 64)	47 (25, 70)	40 (21, 60)	187 (98, 280)
	# D	10 (5, 15)	7 (4, 11)	8 (4, 11)	6 (3, 9)	31 (16, 46)

Notes:

SEIFA, Socioeconomic index for areas, 'index of relative socioeconomic disadvantage'; W&M: women and men; W: women; M: men;

** Total population estimates calculated as the sum of incident cases or deaths for all SEIFA groups combined; estimate range, as calculated using the 95% CI of the RR for each estimate;*

%, proportion of incident cases or deaths potentially attributable to socioeconomic differences in overweight and obesity;

#I Number of incident cases;

#D Number of deaths.

Because our model uses the overweight and obesity prevalence of SEIFA 5 as the reference point, we modelled no reduction in diseases for this quintile.

These primarily relate to differences in the population from which the RR was derived and the analytic population, such as the age range, ethnicity and population prevalence of confounders, as well as controls and adjustments made to calculate the RR. Our estimate for all-cause mortality[43] restricted analyses to 'never smokers' free from chronic disease in order to attain an unbiased estimate for the risk associated with obesity and overweight relative to normal weight.[32] This approach accounts for the competing risk of death among individuals with pre-existing disease and who are current or former smokers, and is therefore less likely to be biased;[48] however, the number of deaths expected to be avoided if the prevalence of overweight and obesity were changed is likely to be overestimated.[48]

Finally, the annual direct healthcare cost estimates for this study come from a cohort of 6,140 Australian adults aged 25 to 84 years over the period 2000 to 2004–05. The differential retention of individuals with a more favourable health status in longitudinal studies means these cost estimates are likely to be an underestimation of the costs for the total population.

Implications and conclusions

Our study was the first to estimate the direct healthcare cost associated with the unequal distribution of overweight and obesity across the socioeconomic spectrum. An important assumption of our study is that the direct healthcare costs associated with normal weight, overweight and obesity are constant across SEIFA quintiles. Contemporary estimates of the direct healthcare costs associated with overweight and obesity for each socioeconomic group will be required to refine this estimate and strengthen the conclusions of the current study.

We modelled the disease burden and direct healthcare costs associated with the unequal distribution of overweight and obesity to better understand the importance of considering equity in all overweight and obesity treatment and prevention initiatives. Our results clearly demonstrate that reducing the socioeconomic gradient in obesity can reduce the socioeconomic gradient in the incidence and death for a range of diseases and reduce healthcare spending. Achieving equitable population obesity prevention will require a suite of obesity prevention, management and treatments, where the health benefits are proportionate to the level of disadvantage. However, our RCI and ACI findings indicate that even after accounting for the impact of the socioeconomic gradient in overweight and obesity, an observed socioeconomic gradient in all diseases modelled remains. Addressing these inequalities in ill-health is therefore likely to require action on other risk factors for non-communicable diseases, such as smoking, as well as the upstream environmental drivers of disease[49] and action on the social determinants of health.[50]

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Supporting Information

Additional supporting information may be found in the online version of this article:

Supplementary Table 1: Source year(s) of input data used.

Supplementary Table 2: Calculation of age- .and SEIFA-specific disease input data

Supplementary Table 3: Estimate for the increased likelihood of each disease outcome for women and men with overweight or obesity compared to women and men with normal weight.

Supplementary Table 4: The age-standardised observed and counterfactual prevalence of normal weight, overweight and obesity for Australian women and men aged 20 to 84 years, and women aged 50 to 84 years, in 2016.

Supplementary File A: Detailed input data description.

Supplementary File B: Detailed statistical methodology.