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Deaths and premature loss of life caused by overweight and obesity in Australia in 2011- 2050: Benefits from different intervention scenarios

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Report for the Australian Preventative Health Taskforce

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Executive summary

The prevalence of overweight and obesity in Australia has been increasing steadily over the past 30 years[1]. According to the National Preventative Health Taskforce's discussion paper: *Australia the healthiest country by 2020,* it has been estimated that if current trends continue unabated over the next 20 years, nearly three-quarters of the Australian population will be overweight or obese in 2025[1].

This report outlines the analyses undertaken to estimate the deaths and premature years of lost life (PYLL) caused by overweight and obesity in Australia in 2011-2050, based on different scenarios.

The results reveal the burden of mortality that will eventuate over the next 40 years if nothing is done to halt or reverse the current overweight/obesity trends in Australia. Additionally, the results give an indication of the potential deaths and PYLL to be saved if effective action is taken to reduce overweight/obesity. The results show that strategies targeting a reduction in the prevalence of overweight/obesity at a whole of population level will be most effective. If only children are targeted progress will be very slow.

The table overleaf gives a summary of the deaths and PYLL under the different scenarios, including changes relative to the scenario where current trends continue into the future. From this table the following key findings are evident:

- If current upward trends in overweight/obesity continue, there will be approximately 1.75 million deaths at ages 20+ years and 10.3 million PYLL at ages 20-74 years caused by overweight/obesity in Australia in 2011 to 2050. Each Australian aged 20-74 years who dies from overweight/obesity in 2011 to 2050 will lose, on average, 12 years of life before age 75 years.

- If further increases in overweight/obesity can be averted and prevalences stabilised at 2005 levels, there will be approximately 1.25 million deaths at ages 20+ years and 8.0 million PYLL at ages 20-74 years caused by overweight/obesity in Australia in 2011 to 2050. This represents savings of 0.5 million deaths and 2.3 million PYLL compared with the continuation of increases.

- For each additional 1% proportional reduction in overweight/obesity that can be achieved beyond a stabilisation at 2005 prevalences, approximately an additional 10,000 deaths and 60,000 PYLL will be prevented.

- An effective intervention targeted only at Australian children will have approximately five times less beneficial impact on PYLL caused by overweigh/obesity in 2011 to 2050 than an equivalently effective intervention targeted cross-sectionally at adults and children. The same intervention targeting only children will have approximately 30 times less beneficial impact on the number of deaths caused by overweight/obesity in 2011 to 2050 than an equivalently effective cross-section intervention.

Summary of total deaths and total PYLL for males, females and persons, including changes from Scenario 1					
Scenario	**Sex**	**Number of deaths (20+yr)**	**Difference in deaths from Scenario 1**	**Number of PYLL (20-74yr)**	**Difference in PYLL from Scenario 1**
Scenario 1: The number of PYLL caused by OW/OB, if current upward trends continue with some deceleration	Male	898,259		6,404,159	
	Female	853,386		3,860,884	
	Persons	1,751,645		10,265,043	
Scenario 2: The number of PYLL caused by OW/OB, if cross-section abatement of upward trends (maintenance of 2005 position)	Male	640,315	257,945	4,906,907	1,497,252
	Female	606,228	247,157	3,044,310	816,574
	Persons	1,246,543	505,102	7,951,217	2.313,826
Scenario 3a: The number of PYLL caused by OW/OB, 1% cross-sectional reduction	Male	634,961	263,298	4,867,550	1,536,609
	Female	601,103	252,283	3,020,699	840,185
	Persons	1,236,064	515,581	7,888,249	2,376,794
Scenario 3b: The number of PYLL caused by OW/OB, 3% cross-sectional reduction	Male	624,204	274,056	4,788,363	1,615,796
	Female	590,806	262,579	2,973,155	887,729
	Persons	1,215,010	536,635	7,761,518	2,503,525
Scenario 3c: The number of PYLL caused by OW/OB, 5% cross-sectional reduction	Male	613,377	284,882	4,708,541	1,695,619
	Female	580,449	272,937	2,925,178	935,706
	Persons	1,193,826	557,819	7,633,719	2,631,325
Scenario 4: The number of PYLL caused by OW/OB, Cross-section abatement of upward trends plus the cohort effect of a 5% reduction in children aged 0-14 in 2010	Male	639,186	259,074	4,866,767	1,537,392
	Female	605,681	247,705	3,025,449	835,435
	Persons	1,244,867	506,778	7,892,217	2,372,827

Introduction

In 2008, the National Preventative Health Taskforce released a report and technical paper outlining cause for concern over the obesity epidemic in Australia.[1 2] This increasing trend has been characterised in several studies, which have all suggested the need for interventions to curb the increases.[3 4 5] Proposed interventions have included adopting a small-changes framework, aimed at helping people make conscious small changes in lifestyle behaviours, in combination with policy supports[6]. The United Kingdom's *Foresight Report* recently outlined various scenarios for tackling obesity and how British society might deliver a sustainable response to its obesity pandemic over the next 40 years[7]. Given that the prevalences of overweight and obesity have been increasing in Australia for more than two decades, the Australian Preventative Health Taskforce has set a target to halt and reverse the risk in overweight and obesity prevalence by 2020.[1 2]

The objectives of this analysis were to forecast the total deaths and person-years of lost life caused by overweight/obesity at ages 20+ years in Australia in 2011-2050 under the following four different prevalence scenarios:

1. Current upward trends continue with some deceleration.

2. Cross-sectional abatement of upward trends (stabilising at 2005 prevalence figures).

3. Cross-sectional prevalence reductions relative to 2005 of:
   3a. 1%
   3b. 3%
   3c. 5%

4. Stabilisation at 2005 prevalence figures plus the cohort effect of a 5% reduction in children aged 0-14 years in 2010.

These were the scenarios that the Taskforce asked us to model. We hoped that the results would provide an indication of the burden of premature mortality that will eventuate if nothing is done to curb overweight/obesity in the Australian population compared with the levels of benefits available under different scenarios of taking effective action. Our role was not to make any assessment of the likelihood that any of the reductions were achievable; but rather only to forecast the effect of different reductions in overweight/obesity on future premature mortality.

Methods

Prevalence estimates for overweight and obesity

Prevalence estimates for overweight and obesity were based on those published in a report by the Victorian Department of Human Services.[8] The prevalence projections from this report were preferred as a starting point, because they were the result of combined data from 11 cross-sectional national or state population surveys and the 1995 National Nutrition survey data. We therefore took the view that the Victorian methodology drew on the most comprehensive synthesis of available data sources. Additionally, the Victorian report published prevalences of overweight (BMI 25 to <30) and obesity (BMI 30+) according to five-year age groups, which was the format preferred for our analysis. Prevalence estimates for each of the scenarios in this study were then developed as follows:

- **Scenario 1: Current upward trends continue with some deceleration**
  - A simple linear regression estimation procedure was used, after parabolic-transformation of the prevalences to allow for non-linearity and a gradual deceleration of upwards trends. Parabolic transformation was used in preference to a natural log transformation as it empirically provided more conservative estimates.
  - For each age-sex group, the square was taken for each of the three available data points for 2005, 2015 and 2025 from the Victorian report.
  - Regression co-efficients were calculated according to the equation below[9].

$$\beta_1 = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2}$$

  - The predictive equation of $\beta_0 = \bar{y} - \hat{\beta}_1 \bar{x}$ was used to project the prevalence squared in each year (2011- 2050) for each age-sex group.
  - The projected prevalences squared were then reverse-transformed by taking the square root, resulting in the projected prevalence of overweight or obesity for the particular age-sex group in a given calendar year. Below are sample results from selected calendar years.

Scenario 1: Prevalences of overweight and obesity by age in males

	2011		2020		2030		2040		2050	
	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity
20-24	0.351	0.153	0.422	0.164	0.490	0.176	0.549	0.186	0.602	0.197
25-29	0.463	0.196	0.471	0.252	0.480	0.301	0.488	0.344	0.496	0.382
30-34	0.512	0.242	0.506	0.295	0.500	0.344	0.493	0.387	0.486	0.426
35-39	0.488	0.283	0.479	0.348	0.469	0.409	0.459	0.462	0.448	0.510
40-44	0.510	0.285	0.491	0.355	0.468	0.419	0.444	0.475	0.419	0.525
45-49	0.496	0.341	0.465	0.414	0.427	0.481	0.385	0.540	0.339	0.594
50-54	0.480	0.395	0.445	0.462	0.404	0.527	0.357	0.584	0.304	0.636
55-59	0.518	0.326	0.505	0.375	0.489	0.423	0.473	0.466	0.457	0.506
60-64	0.467	0.388	0.440	0.450	0.408	0.510	0.374	0.564	0.335	0.613
65-69	0.504	0.326	0.466	0.395	0.419	0.460	0.366	0.517	0.304	0.569
70-74	0.480	0.344	0.453	0.415	0.421	0.481	0.387	0.540	0.349	0.593
75-79	0.495	0.330	0.464	0.409	0.427	0.482	0.386	0.545	0.340	0.602
80+	0.473	0.223	0.462	0.284	0.450	0.339	0.437	0.387	0.424	0.429

Scenario 1: Prevalences of overweight and obesity by age in females										
	2011		2020		2030		2040		2050	
	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity
20-24	0.259	0.149	0.311	0.182	0.360	0.213	0.404	0.240	0.443	0.264
25-29	0.307	0.175	0.364	0.209	0.418	0.241	0.466	0.269	0.510	0.295
30-34	0.339	0.227	0.355	0.279	0.371	0.328	0.386	0.370	0.401	0.407
35-39	0.341	0.237	0.371	0.279	0.401	0.319	0.429	0.354	0.455	0.386
40-44	0.394	0.262	0.407	0.328	0.420	0.389	0.434	0.441	0.447	0.487
45-49	0.370	0.322	0.390	0.369	0.410	0.415	0.429	0.456	0.448	0.494
50-54	0.398	0.366	0.398	0.440	0.399	0.509	0.399	0.570	0.400	0.625
55-59	0.411	0.408	0.373	0.493	0.325	0.574	0.268	0.644	0.196	0.707
60-64	0.426	0.385	0.405	0.451	0.380	0.515	0.353	0.572	0.324	0.623
65-69	0.373	0.384	0.362	0.451	0.349	0.515	0.336	0.572	0.322	0.623
70-74	0.388	0.387	0.376	0.453	0.361	0.516	0.345	0.573	0.329	0.624
75-79	0.461	0.314	0.454	0.377	0.446	0.437	0.438	0.489	0.430	0.537
80+	0.435	0.289	0.418	0.353	0.398	0.412	0.378	0.464	0.356	0.510

- **Scenario 2*:* Cross-sectional abatement of upward trends**
  - Prevalence estimates for overweight and obesity were based directly on the age and sex-specific prevalences modeled for 2005 in the Victorian report, which we then applied constantly throughout the 2011 to 2050 year period.

Scenario 2: Prevalences of overweight and obesity by age for males		
	2011 to 2050	
	O/weight	Obesity
20-24	0.297	0.146
25-29	0.448	0.162
30-34	0.515	0.205
35-39	0.481	0.238
40-44	0.526	0.224
45-49	0.509	0.295
50-54	0.497	0.346
55-59	0.525	0.293
60-64	0.484	0.346
65-69	0.526	0.276
70-74	0.492	0.299
75-79	0.522	0.261
80+	0.478	0.178

Scenario 2: Prevalences of overweight and obesity by age for females		
	2011 to 2050	
	O/weight	Obesity
20-24	0.210	0.130
25-29	0.259	0.152
30-34	0.327	0.184
35-39	0.325	0.206
40-44	0.393	0.209
45-49	0.348	0.292
50-54	0.391	0.311
55-59	0.428	0.356
60-64	0.441	0.339
65-69	0.375	0.343
70-74	0.389	0.348
75-79	0.457	0.271
80+	0.440	0.240

- **Scenario 3: Cross-sectional reductions relative to 2005 of 1%, 3% and 5%**
  - The age-sex-specific overweight/obesity prevalence estimates from Scenario 2 were reduced proportionally by 1%, 3%, and 5% in three separate analyses. Note that the percent reductions were relative to baseline and not absolute percentage subtractions from baseline.

Scenario 3: Reductions in prevalences of overweight and obesity by age, 2011- 2050 for males						
	1% Reduction		3% Reduction		5% Reduction	
	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity
20-24	0.294	0.145	0.288	0.142	0.282	0.139
25-29	0.444	0.160	0.435	0.157	0.426	0.154
30-34	0.510	0.203	0.500	0.199	0.489	0.195
35-39	0.476	0.236	0.467	0.231	0.457	0.226
40-44	0.521	0.222	0.510	0.217	0.500	0.213
45-49	0.504	0.292	0.494	0.286	0.484	0.280
50-54	0.492	0.343	0.482	0.336	0.472	0.329
55-59	0.520	0.290	0.509	0.284	0.499	0.278
60-64	0.479	0.343	0.469	0.336	0.460	0.329
65-69	0.521	0.273	0.510	0.268	0.500	0.262
70-74	0.487	0.296	0.477	0.290	0.467	0.284
75-79	0.517	0.258	0.506	0.253	0.496	0.248
80+	0.473	0.176	0.464	0.173	0.454	0.169

Scenario 3: Reductions in prevalences of overweight and obesity by age, 2011- 2050 for females						
	1% Reduction		3% Reduction		5% Reduction	
	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity
20-24	0.208	0.129	0.204	0.126	0.200	0.124
25-29	0.256	0.150	0.251	0.147	0.246	0.144
30-34	0.324	0.182	0.317	0.178	0.311	0.175
35-39	0.322	0.204	0.315	0.200	0.309	0.196
40-44	0.389	0.207	0.381	0.203	0.373	0.199
45-49	0.345	0.289	0.338	0.283	0.331	0.277
50-54	0.387	0.308	0.379	0.302	0.371	0.295
55-59	0.424	0.352	0.415	0.345	0.407	0.338
60-64	0.437	0.336	0.428	0.329	0.419	0.322
65-69	0.371	0.340	0.364	0.333	0.356	0.326
70-74	0.385	0.345	0.377	0.338	0.370	0.331
75-79	0.452	0.268	0.443	0.263	0.434	0.257
80+	0.436	0.238	0.427	0.233	0.418	0.228

- **Scenario 4: Stabilisation at 2005 prevalence figures plus the cohort effect of a 5% reduction in children aged 0-14 in 2010**
  - This scenario was based on there being a 5% proportion reduction (from a baseline equal to 2005 prevalences from Scenario 2) in overweight/obesity prevalence at ages 0-14 years in 2010, which worked its way through the population to the extent possible over the following 40 years.
  - For calendar years 2011 to 2015, there was no change at ages 20+ years, therefore the 2005 prevalences were used.
  - For 2016 to 2020 the prevalences at ages 20-24 only were reduced by an additional 1% each year, i.e. reduced by 1% in 2016, 2% in 2017, 3% in 2018, 4% in 2019 and by the full 5% in 2020. The 2005 prevalences were applied to ages 25+ years.
  - For 2021 to 2025, the 5% reduction at ages 20-24 years was kept constant. The prevalences at ages 25-29 years were now progressively reduced by 1% for each calendar year, i.e. by 1% in 2021, 2% in 2022, 3% in 2023, 4% in 2024 and by the full 5% in 2025. The 2005 prevalences were applied to ages 30+ years.
  - For 2026 to 2030, prevalences at ages 20-24 and 25-29 years were constantly reduced by 5% relative to the 2005 measures, and the 1% per year progressive reductions were applied only to ages 30-34 years. The 2005 prevalences were applied to ages 35+ years.
  - This pattern of application of the methodology was repeated until upon reaching the calendar years 2046-2050, prevalences at the age groups from 20-24 to 45-49 were constantly reduced by 5% relative to 2005, whereas just the measures at ages 50-54 years were progressively reduced by 1% in each calendar year. At ages 55+ years, the prevalences remained constant at the 2005 level throughout the entire period.

Scenario 4: Prevalences of overweight and obesity by age in males with percentage prevalence reductions targeting children in 2010

	2011		2020		2030		2040		2050	
	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity
5-9	0.133	0.055	0.133	0.055	0.133	0.055	0.133	0.055	0.133	0.055
10-14	0.206	0.041	0.206	0.041	0.206	0.041	0.206	0.041	0.206	0.041
15-19	0.218	0.072	0.209	0.069	0.209	0.069	0.209	0.069	0.209	0.069
20-24	0.297	0.146	0.282	0.139	0.282	0.139	0.282	0.139	0.282	0.139
25-29	0.448	0.162	0.448	0.162	0.426	0.154	0.426	0.154	0.426	0.154
30-34	0.515	0.205	0.515	0.205	0.515	0.205	0.489	0.195	0.489	0.195
35-39	0.481	0.238	0.481	0.238	0.481	0.238	0.481	0.238	0.457	0.226
40-44	0.526	0.224	0.526	0.224	0.526	0.224	0.526	0.224	0.526	0.224
45-49	0.509	0.295	0.509	0.295	0.509	0.295	0.509	0.295	0.509	0.295
50-54	0.497	0.346	0.497	0.346	0.497	0.346	0.497	0.346	0.497	0.346
55-59	0.525	0.293	0.525	0.293	0.525	0.293	0.525	0.293	0.525	0.293
60-64	0.484	0.346	0.484	0.346	0.484	0.346	0.484	0.346	0.484	0.346
65-69	0.526	0.276	0.526	0.276	0.526	0.276	0.526	0.276	0.526	0.276
70-74	0.492	0.299	0.492	0.299	0.492	0.299	0.492	0.299	0.492	0.299
75-79	0.522	0.261	0.522	0.261	0.522	0.261	0.522	0.261	0.522	0.261
80+	0.478	0.178	0.478	0.178	0.478	0.178	0.478	0.178	0.478	0.178

Scenario 4: Prevalences of overweight and obesity by age in females with percentage prevalence reductions targeting children in 2010										
	2011		2020		2030		2040		2050	
	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity	O/weight	Obesity
5-9	0.189	0.067	0.189	0.067	0.189	0.067	0.189	0.067	0.189	0.067
10-14	0.178	0.055	0.178	0.055	0.178	0.055	0.178	0.055	0.178	0.055
15-19	0.172	0.056	0.165	0.054	0.165	0.054	0.165	0.054	0.165	0.054
20-24	0.210	0.130	0.200	0.124	0.200	0.124	0.200	0.124	0.200	0.124
25-29	0.259	0.152	0.259	0.152	0.246	0.144	0.246	0.144	0.246	0.144
30-34	0.327	0.184	0.327	0.184	0.327	0.184	0.311	0.175	0.311	0.175
35-39	0.325	0.206	0.325	0.206	0.325	0.206	0.325	0.206	0.309	0.196
40-44	0.393	0.209	0.393	0.209	0.393	0.209	0.393	0.209	0.393	0.209
45-49	0.348	0.292	0.348	0.292	0.348	0.292	0.348	0.292	0.348	0.292
50-54	0.391	0.311	0.391	0.311	0.391	0.311	0.391	0.311	0.391	0.311
55-59	0.428	0.356	0.428	0.356	0.428	0.356	0.428	0.356	0.428	0.356
60-64	0.441	0.339	0.441	0.339	0.441	0.339	0.441	0.339	0.441	0.339
65-69	0.375	0.343	0.375	0.343	0.375	0.343	0.375	0.343	0.375	0.343
70-74	0.389	0.348	0.389	0.348	0.389	0.348	0.389	0.348	0.389	0.348
75-79	0.457	0.271	0.457	0.271	0.457	0.271	0.457	0.271	0.457	0.271
80+	0.440	0.240	0.440	0.240	0.440	0.240	0.440	0.240	0.440	0.240

Mortality rate ratios

The rate ratios were based on the results reported by Calle *et al* in 1999[10] from the Cancer Prevention Study II, a prospective cohort study of 1.2 million men and women in the United States that was begun by the American Cancer Society in 1982. Calle *et al* report age and sex-specific mortality rate ratios in relation to different interval ranges of body mass index, which were amenable to being collapsed into the three exposure categories of 'neither overweight nor obese', 'overweight but not obese' and 'obese' use in this analysis. The results published by Calle *et al* were preferred over alternatives because they were derived from a large study and therefore precise; were more finely stratified than those in other reports; and were tractable in terms of our category requirements. The mortality rate ratios derived from the report by Calle *et al* were as follows:

Overweight and obesity rate ratios				
	RR Overweight		RR Obese	
	Males	Females	Males	Females
<65 years	1.15	1.31	1.73	1.64
65- 74 years	1.15	1.21	1.72	1.76
75+ years	1.03	1.03	1.20	1.27

Aetiologic fractions

The aetiologic fractions were calculated using a combination of the above prevalence estimates and mortality rate ratios. The composite age and sex-specific aetiologic fractions of deaths from overweight and obesity together were derived from the sum of the respective partial aetiologic fractions. Thus for the ith age-sex group the composite aetiologic fraction of deaths caused by overweight and obesity was calculated according to the formula below.[11]

$$F_i = \frac{\sum_{j=1}^{k} p_{j,i}(MRR_{j,i} - 1)}{\sum_{j=0}^{k} p_{j,i}(MRR_{j,i} - 1) + 1} = \frac{\left[p_{ow,i}(MRR_{ow,i} - 1)\right] + \left[p_{ob,i}(MRR_{ob,i} - 1)\right]}{\left[p_{ow,i}(MRR_{ow,i} - 1)\right] + \left[p_{ob,i}(MRR_{ob,i} - 1)\right] + 1}$$

where $MRR_{j,i}$ is the mortality rate ratio in the ith age-sex group for the jth exposure category, pj,i is the prevalence of jth exposure category in the ith age-sex group and j=0 is the baseline (non-exposed) category, in this instance neither overweight (ow) nor obese (ob). The aetiologic fractions were calculated separately for each study scenario.

- **Scenario I: Current upward trends continue with some deceleration**
  - Matrices of overweight and obesity prevalences by age group and calendar year were combined with the corresponding vectors of rate ratios by age group in males and females for overweight and obesity to derive the following aetiologic fractions for overweight/obesity combined:

Scenario 1: Aetiologic fractions of overweight/obesity by age and sex										
	Males					Females				
	2011	2020	2030	2040	2050	2011	2020	2030	2040	2050
20-24	0.140	0.149	0.153	0.176	0.166	0.199	0.178	0.218	0.188	0.234
25-29	0.174	0.171	0.201	0.197	0.225	0.221	0.244	0.240	0.260	0.257
30-34	0.201	0.200	0.224	0.224	0.245	0.245	0.262	0.263	0.276	0.278
35-39	0.217	0.205	0.245	0.227	0.268	0.247	0.288	0.264	0.304	0.279
40-44	0.220	0.225	0.248	0.251	0.272	0.275	0.291	0.294	0.307	0.310
45-49	0.243	0.243	0.270	0.263	0.292	0.282	0.310	0.298	0.325	0.313
50-54	0.264	0.263	0.287	0.288	0.307	0.310	0.323	0.328	0.337	0.344
55-59	0.239	0.280	0.258	0.301	0.275	0.319	0.290	0.331	0.303	0.339
60-64	0.260	0.274	0.282	0.293	0.301	0.309	0.318	0.322	0.331	0.333
65-69	0.238	0.270	0.263	0.295	0.284	0.317	0.301	0.335	0.314	0.351
70-74	0.244	0.273	0.270	0.297	0.292	0.319	0.310	0.337	0.325	0.352
75-79	0.074	0.091	0.086	0.105	0.097	0.117	0.106	0.128	0.114	0.137
80+	0.055	0.085	0.065	0.098	0.074	0.111	0.082	0.121	0.088	0.130

- **Scenario 2*:* Cross-sectional abatement of upward trends**
  - The same methods as in Scenario 1 were followed, but using the constant Scenario 2 prevalence figures based on the Victorian report for 2005.

Scenario 2: Aetiologic Fractions of overweight/obesity by age and sex		
	2011 to 2050	
	Males	Females
20-24	0.130	0.129
25-29	0.155	0.151
30-34	0.184	0.180
35-39	0.196	0.189
40-44	0.194	0.203
45-49	0.224	0.227
50-54	0.245	0.242
55-59	0.225	0.265
60-64	0.244	0.261
65-69	0.219	0.253
70-74	0.226	0.257
75-79	0.063	0.081
80+	0.047	0.074

- **Scenario 3: Cross-sectional reductions relative to 2005 of 1%, 3% and 5%**
  - The same methods as in Scenario 1 were followed, but using the Scenario 3 prevalence figures based on 1%, 3%, and 5% proportional reductions from the 2005 data in the Victorian report.

Scenario 3: Aetiologic fractions of overweight/obesity by age and sex, based on percentage prevalence reductions, 2011- 2050						
	Males			Females		
	1%	3%	5%	1%	3%	5%
20-24	0.129	0.127	0.125	0.128	0.126	0.123
25-29	0.154	0.151	0.149	0.149	0.147	0.144
30-34	0.182	0.179	0.176	0.178	0.175	0.172
35-39	0.194	0.191	0.188	0.187	0.184	0.181
40-44	0.192	0.189	0.186	0.202	0.198	0.195
45-49	0.223	0.219	0.216	0.226	0.222	0.219
50-54	0.243	0.240	0.236	0.241	0.237	0.233
55-59	0.223	0.220	0.216	0.263	0.259	0.255
60-64	0.242	0.238	0.235	0.259	0.255	0.251
65-69	0.217	0.214	0.210	0.251	0.248	0.244
70-74	0.224	0.221	0.217	0.255	0.251	0.247
75-79	0.062	0.061	0.060	0.080	0.079	0.077
80+	0.047	0.046	0.045	0.073	0.072	0.070

- **Scenario 4: Stabilisation at 2005 prevalence figures plus the cohort effect of a 5% reduction in children aged 0-14 in 2010**
  - The same methods as in Scenario 1 were followed, but using the Scenario 4 prevalence figures based on a 5% proportion reduction in prevalence in children aged 0-14 in 2010 onwards relative to the 2005 figures in the Victorian report.

Scenario 4: Aetiologic fractions of overweight/obesity by age and sex with percentage prevalence reductions targeting children in 2010										
	Males					Females				
	2011	2020	2030	2040	2050	2011	2020	2030	2040	2050
5-9	0.056	0.056	0.056	0.056	0.056	0.092	0.092	0.092	0.092	0.092
10-14	0.057	0.057	0.057	0.057	0.057	0.083	0.083	0.083	0.083	0.083
15-19	0.078	0.075	0.075	0.075	0.075	0.082	0.079	0.079	0.079	0.079
20-24	0.130	0.125	0.125	0.125	0.125	0.129	0.123	0.123	0.123	0.123
25-29	0.155	0.155	0.149	0.149	0.149	0.151	0.151	0.144	0.144	0.144
30-34	0.184	0.184	0.176	0.176	0.176	0.180	0.180	0.172	0.172	0.172
35-39	0.196	0.196	0.196	0.188	0.188	0.189	0.189	0.189	0.181	0.181
40-44	0.194	0.194	0.194	0.186	0.186	0.203	0.203	0.203	0.195	0.195
45-49	0.224	0.224	0.224	0.224	0.216	0.227	0.227	0.227	0.227	0.219
50-54	0.245	0.245	0.245	0.245	0.236	0.242	0.242	0.242	0.242	0.233
55-59	0.225	0.225	0.225	0.225	0.225	0.265	0.265	0.265	0.265	0.265
60-64	0.244	0.244	0.244	0.244	0.244	0.261	0.261	0.261	0.261	0.261
65-69	0.219	0.219	0.219	0.219	0.219	0.253	0.253	0.253	0.253	0.253
70-74	0.226	0.226	0.226	0.226	0.226	0.257	0.257	0.257	0.257	0.257
75-79	0.063	0.063	0.063	0.063	0.063	0.081	0.081	0.081	0.081	0.081
80+	0.047	0.047	0.047	0.047	0.047	0.074	0.074	0.074	0.074	0.074

Deaths

Death rates in the Australian population were calculated using information provided in the 2005-2007 Life Tables for Australia, obtained from the Australian Bureau of Statistics.[12] The number of deaths (d_x) were calculated by multiplying l_x (the number of persons-alive at age x) by q_x (the cumulative mortality risk in the age interval x to x+1). After the numbers of deaths (d_x) and the person-years lived within the age interval x to x+1 (L_x) were grouped by five-year age group and sex, the deaths were divided by person-years to give the mortality rate for each age and sex group. These mortality rates are shown in the table on the right.

2005-2007 Australian mortality rates by five-year age group

	Mortality rates	
	Males	**Females**
20-24	0.00079	0.00028
25-29	0.00088	0.00033
30-34	0.00104	0.00043
35-39	0.00123	0.00062
40-44	0.00164	0.00096
45-49	0.00242	0.00147
50-54	0.00357	0.00218
55-59	0.00547	0.00328
60-64	0.00891	0.00528
65-69	0.01463	0.00833
70-74	0.02391	0.01408
75-79	0.04203	0.02555
80+	0.11803	0.09665

Projected Australian population estimates were obtained from the Australian Bureau of Statistics, and grouped by five-year age group (up to 85+ years) and sex for each year from 2011 to 2050.[13] The sums of the populations were calculated to give person-years at risk in each age group and sex combination for the entire 40-year period. The population projections were based on trends in fertility, life expectancy at birth, net overseas migration and net interstate migration.[13] These population projections are shown in the two tables below.

Australian population projections for years 2011, 2020, 2030, 2040 and 2050 for males

	Males					
	2011	**2020**	**2030**	**2040**	**2050**	**2011-2050 Total**
20-24	805,039	840,913	913,608	986,842	1,039,525	36,730,647
25-29	816,140	909,318	919,767	1,019,059	1,083,566	38,141,259
30-34	762,507	914,687	963,882	1,036,642	1,109,931	38,750,468
35-39	782,225	895,739	1,004,874	1,015,857	1,115,031	38,587,916
40-44	785,733	813,897	982,813	1,032,280	1,105,149	38,100,475
45-49	773,384	832,564	935,408	1,044,079	1,055,965	36,983,636
50-54	737,302	776,694	825,971	993,175	1,043,160	35,492,477
55-59	668,232	767,500	824,209	926,432	1,034,457	33,469,473
60-64	619,392	702,775	758,016	807,898	972,313	31,075,836
65-69	473,932	620,431	733,269	790,543	891,548	28,245,561
70-74	355,633	544,764	645,476	701,429	752,100	24,677,385
75-79	261,747	374,000	528,422	632,456	689,425	20,363,349
80+	340,297	450,803	718,454	988,233	1,197,934	29,554,834
						430,173,316

Australian population projections for years 2011, 2020, 2030, 2040 and 2050 for females						
	Females					
	2011	2020	2030	2040	2050	2011-2050 Total
20-24	765,006	800,784	871,133	939,946	989,798	34,964,969
25-29	796,340	870,895	882,033	977,782	1,038,822	36,628,850
30-34	757,109	887,825	933,484	1,003,804	1,072,577	37,613,040
35-39	790,036	884,783	975,154	986,434	1,082,066	37,741,622
40-44	795,461	815,253	960,604	1,006,295	1,076,550	37,538,613
45-49	785,300	847,082	928,659	1,018,725	1,030,331	36,694,929
50-54	755,462	790,551	832,838	977,157	1,022,948	35,544,160
55-59	681,259	789,214	846,873	928,108	1,017,638	33,874,892
60-64	627,912	729,911	781,861	824,326	966,701	31,834,418
65-69	481,499	649,028	769,208	826,608	907,034	29,338,418
70-74	377,824	573,694	694,539	746,272	788,730	26,259,687
75-79	300,273	412,531	590,284	703,106	758,960	22,620,414
80+	527,821	635,276	940,921	1,294,464	1,543,892	39,409,581
						440,063,593

Multiplying the above 2005-07 mortality rates by the Australian population projections resulted in projected total deaths by age group and sex for each calendar year during the 40-year period of 2011-2050 as indicated in the tables below.

Total projected deaths by age for years 2011, 2020, 2030, 2040 and 2050 for males						
	Males					
	2011	2020	2030	2040	2050	2011-2050 Total
20-24	638	666	724	782	824	29,102
25-29	718	800	810	897	954	33,577
30-34	793	952	1,003	1,079	1,155	40,319
35-39	959	1,099	1,233	1,246	1,368	47,333
40-44	1,289	1,336	1,613	1,694	1,814	62,521
45-49	1,870	2,013	2,262	2,525	2,553	89,426
50-54	2,634	2,775	2,951	3,548	3,727	126,793
55-59	3,655	4,198	4,508	5,067	5,658	183,061
60-64	5,516	6,259	6,751	7,195	8,659	276,756
65-69	6,936	9,080	10,731	11,569	13,048	413,364
70-74	8,501	13,023	15,430	16,768	17,979	589,918
75-79	11,000	15,717	22,207	26,579	28,973	855,775
80+	40,164	53,206	84,796	116,636	141,386	3,488,210
						6,236,154

Total projected deaths by age for years 2011, 2020, 2030, 2040 and 2050 for females						
	Females					
	2011	2020	2030	2040	2050	2011-2050 Total
20-24	217	227	247	267	281	9,931
25-29	264	289	293	325	345	12,162
30-34	327	384	403	434	463	16,252
35-39	492	550	607	614	673	23,480
40-44	762	781	921	964	1,032	35,973
45-49	1,152	1,242	1,362	1,494	1,511	53,821
50-54	1,645	1,722	1,814	2,128	2,228	77,403
55-59	2,235	2,590	2,779	3,045	3,339	111,156
60-64	3,317	3,856	4,131	4,355	5,107	168,181
65-69	4,011	5,406	6,407	6,885	7,555	244,370
70-74	5,320	8,077	9,779	10,507	11,105	369,729
75-79	7,673	10,541	15,083	17,966	19,394	578,014
80+	51,015	61,401	90,943	125,114	149,222	3,809,054
						5,509,527

PYLL

It is possible to estimate the person-years of life lost as a result of exposure of the population to a particular condition, in this case overweight/obesity denoted in our formulation as cause of death k. The potential PYLL in the ith age group due to cause of death k, (S_{ik}), was estimated using the method of Hakulinen and Teppo (1976) formulated below:[9]

$$S_{ik} = n_i \left\{ \sum_{x=0}^{i-1} d_{xk} \sqrt{p_{x.k}} P_{x+1,i.k} \left[a_i (1 - p_{i.k}) + p_{i.k} \right] + \tfrac{1}{2} d_{ik} (1 - a_i) \left(1 + \sqrt{p_{i.k}} \right) \right\}$$

where

a_i = average proportion of time lived in the ith age group by people who die in the group;

n_i = the width of the ith age group (all five years);

d_{ik} = the number of deaths due to k in the ith age interval; and

$p_{i.k}$ = the conditional probability of survival in the ith age interval after elimination of k as a cause of death.

and

$$P_{x+1,i.k} = \left\{ \begin{matrix} \prod_{v=x+1}^{i-1} p_{v.k} & , x+1 < i \\ 1 & , x+1 = i \end{matrix} \right\}$$

Note that for a particular drug, sex and condition,

$$d_{ik} = I^*_{hijk} = F_{hijk} \,.\, I_{ijk}$$

Whereas for a particular drug and sex (i.e., summed over all drug-caused conditions),

$$d_{ik} = I^*_{hij} = \sum_k F_{hijk} \,.\, I_{ijk}$$

The method of calculation of $p_{i.k}$ is as follows[14]

$$p_{i.k} = p_i^{(d_i - d_{ik})/d_i}$$

where

d_i = the total number of deaths in ith age interval;

p_i = the conditional probability of survival from all causes of death in the ith age interval, calculated by the formula

$$p_i = \frac{1 - a_i n_i M_i}{1 + (1 - a_i) n_i M_i}$$

where M_i = the all-cause mortality rate in the ith age interval.

It is important to note that the age-specific PYLL are assigned to the age groups in which potential years of life would be gained upon elimination of a cause of death, and not to the age groups in which the deaths occurred. Therefore, the PYLL from ages 20-24 to 70-74 years were estimated by summing the S_{ik} over that range of age groups. We chose age 75 years as the cut off for premature mortality as being more appropriate, given life expectancies in Australia in 2009, than a common practice from researchers to use a cut off of age 70 years.

The formulae above were implemented in a PYLL spreadsheet template created in Microsoft Excel along with the necessary data inputs to calculate the PYLL for all years combined for each scenario.

Results:

Deaths caused by overweight and obesity

The two tables below show the total numbers of deaths for the combined years 2011 to 2050 in males and females, caused by overweight/obesity by age under each scenario. These totals indicate that doing nothing, as in Scenario 1, and letting the current trends continue albeit decelerating will result in the highest number of total deaths. This compares with halting the current trend (Scenario 2), applying effective interventions to all age groups, leading to cross-sectional percentage reductions in prevalence (Scenario 3), and an effective intervention only targeting children (Scenario 4), all of which lead to a decrease in the total number of deaths. However, the largest beneficial impact on death counts was obtained from an effective intervention applied cross-sectionally to the whole population.

Total deaths caused by overweight/obesity by age for each scenario (2011-2050): Males

	Males					
	Scenario 1	**Scenario 2**	**Scenario 3 1%**	**Scenario 3 3%**	**Scenario 3 5%**	**Scenario 4**
20-24	4,862	3,793	3,760	3,693	3,627	3,653
25-29	7,543	5,210	5,166	5,077	4,988	5,049
30-34	9,884	7,400	7,339	7,218	7,095	7,215
35-39	12,734	9,279	9,204	9,053	8,902	9,095
40-44	17,041	12,110	12,013	11,816	11,617	11,934
45-49	26,187	20,072	19,916	19,602	19,285	19,894
50-54	38,998	31,084	30,849	30,375	29,896	30,980
55-59	50,635	41,188	40,868	40,224	39,573	41,188
60-64	83,723	67,548	67,036	66,004	64,963	67,548
65-69	117,792	90,503	89,795	88,369	86,930	90,503
70-74	173,722	133,202	132,168	130,087	127,987	133,202
75-79	84,997	53,928	53,422	52,409	51,393	53,928
80+	270,143	164,999	163,426	160,276	157,120	164,999
TOTAL	**898,259**	**640,315**	**634,961**	**624,204**	**613,377**	**639,186**

Total deaths caused by overweight/obesity by age for each scenario (2011-2050): Females

	Females					
	Scenario 1	**Scenario 2**	**Scenario 3 1%**	**Scenario 3 3%**	**Scenario 3 5%**	**Scenario 4**
20-24	1,976	1,281	1,270	1,248	1,225	1,234
25-29	2,690	1,832	1,817	1,785	1,754	1,775
30-34	3,988	2,918	2,894	2,846	2,797	2,845
35-39	5,820	4,427	4,391	4,318	4,245	4,339
40-44	9,900	7,316	7,257	7,140	7,021	7,202
45-49	15,227	12,243	12,149	11,958	11,765	12,137
50-54	24,051	18,761	18,619	18,332	18,042	18,699
55-59	35,320	29,433	29,216	28,779	28,337	29,433
60-64	52,060	43,907	43,581	42,926	42,263	43,907
65-69	77,902	61,907	61,444	60,510	59,566	61,907
70-74	118,928	95,046	94,338	92,911	91,469	95,046
75-79	69,398	46,921	46,489	45,624	44,757	46,921
80+	436,126	280,236	277,638	272,430	267,207	280,236
TOTAL	**853,386**	**606,228**	**601,103**	**590,806**	**580,449**	**605,681**

The summary table below gives a clearer indication of the numbers of deaths saved under each scenario compared with the current upward trends continuing, as in Scenario 1. The percentage reductions under Scenario 3 of 1%, 3% and 5% result in the greatest reduction of total deaths, compared with Scenario 1, for all persons at 515,102; 536,635; and 557,819 respectively. When these same percentage reductions were applied only to persons between the ages of 20 and 74 years the savings in deaths from Scenario 1 were 195,894; 206,712; and 217,634 respectively (not shown in table).

Scenario 2 and 4 were fairly similar in the total number of deaths saved at 505,102 and 506,778 respectively. When applied only to persons between the ages of 20 and 74 years these same Scenario's 2 and 4, gave a savings of total deaths of 190,522 and 192,199 respectively (not shown in table). This shows that there is little difference in projected savings of deaths between halting the current trends or halting the current trends plus reducing the prevalence in children.

Summary of total deaths for ages 20+ combined for males, females and persons, including changes from Scenario 1

Scenario	Sex	Number of deaths (20+yr)	Difference in deaths from Scenario 1
Scenario 1: The number of PYLL caused by OW/OB, if current upward trends continue with some deceleration	Male	898,259	
	Female	853,386	
	Persons	1,751,645	
Scenario 2: The number of PYLL caused by OW/OB, if cross-section abatement of upward trends (maintenance of 2005 position)	Male	640,315	257,945
	Female	606,228	247,157
	Persons	1,246,543	505,102
Scenario 3a: The number of PYLL caused by OW/OB, 1% cross-sectional reduction	Male	634,961	263,298
	Female	601,103	252,283
	Persons	1,236,064	515,581
Scenario 3b: The number of PYLL caused by OW/OB, 3% cross-sectional reduction	Male	624,204	274,056
	Female	590,806	262,579
	Persons	1,215,010	536,635
Scenario 3c: The number of PYLL caused by OW/OB, 5% cross-sectional reduction	Male	613,377	284,882
	Female	580,449	272,937
	Persons	1,193,826	557,819
Scenario 4: The number of PYLL caused by OW/OB, Cross-section abatement of upward trends plus the cohort effect of a 5% reduction in children aged 0-14 in 2010	Male	639,186	259,074
	Female	605,681	247,705
	Persons	1,244,867	506,778

PYLL caused by overweight and obesity

If the current upward trends of overweight and obesity were to continue, as per Scenario 1, the future PYLL at ages 20 to 74 years in Australia were estimated to be 5,404,159 and 3,860,884 in males and females respectively (total persons= 10,265,043).

As was the case with total deaths in the tables above, cross-sectional reductions in overweight/obesity prevalence as per Scenario 3 saved the most PYLL when compared with Scenario 1. These savings were 2,376,795; 2,503,525; and 2,631,325 PYLL after reductions of 1%, 3% and 5% respectively.

Scenario 4 assumed that beyond curbing future cross-sectional increases, effective interventions will occur only in children, with proportional reductions in prevalence gradually extending up the age groups as a cohort effect over time. If such a scenario were to eventuate, the future number of PYLL at ages 20 to 74 years caused by overweight/obesity in Australia in 2011-2050 would be 4,866,767 and 3,025,449 in males and females respectively. This resulted in a difference in the total PYLL for persons, from Scenario 1, of 2,373,827.

Dividing the PYLL by deaths at ages 20-74 years under Scenario 1 provided the average number of years of lost life before age 75 years from each premature death due to overweight/obesity, being 12 PYLL for all persons.

Summary of total PYLL for ages 20-74 combined for males, females and persons, including changes from Scenario 1

Scenario	Sex	Number of PYLL (20-74)	Difference in PYLL from Scenario 1
Scenario 1: The number of PYLL caused by OW/OB, if current upward trends continue with some deceleration	Male	6,404,159	
	Female	3,860,884	
	Persons	10,265,043	
Scenario 2: The number of PYLL caused by OW/OB, if cross-section abatement of upward trends (maintenance of 2005 position)	Male	4,906,907	1,497,252
	Female	3,044,310	816,574
	Persons	7,951,217	2,313,826
Scenario 3a: The number of PYLL caused by OW/OB, 1% cross-sectional reduction	Male	4,867,550	1,536,609
	Female	3,020,699	840,185
	Persons	7,888,249	2,376,795
Scenario 3b: The number of PYLL caused by OW/OB, 3% cross-sectional reduction	Male	4,788,363	1,615,796
	Female	2,973,155	887,729
	Persons	7,761,518	2,503,525
Scenario 3c: The number of PYLL caused by OW/OB, 5% cross-sectional reduction	Male	4,708,541	1,695,619
	Female	2,925,178	935,706
	Persons	7,633,719	2,631,325
Scenario 4: The number of PYLL caused by OW/OB, Cross-section abatement of upward trends plus the cohort effect of a 5% reduction in children aged 0-14 in 2010	Male	4,866,767	1,537,392
	Female	3,025,449	835,435
	Persons	7,892,217	2,372,827

Discussion

The results of this analysis give an indication of the burden of mortality that will eventuate over the next 40 years if nothing is done to halt or reverse the current overweight/obesity trends in Australia. There are many potential deaths and person-years of lost life to be saved if effective action is taken to reduce overweight/obesity. The results show that strategies targeting a reduction in the prevalence of overweight/obesity at a whole-of-population level will be most effective. If only children are targeted progress will be very slow.

We emphasise that the estimated prevalences of overweight and obesity used in Scenario 1 were purposely constructed so as to obtain conservative estimates. This was due to the parabolic-transformation method undertaken prior to linear regression estimation (to allow for non-linearity) as opposed to a natural log transformation method or an untransformed linear projection. The parabolic transformation method empirically provided the most conservative estimates from among several alternative regression models that we explored.

Scenario 2 assumed that the mortality rates in Australia in 2005-2007 will remain constant in the future up to 2050. This assumption is most certainly a weak one in the general sense, but it is also the appropriate assumption to use in an analysis where the mortality rate ratios underlying the aetiologic fractions are also assumed to be held constant into the future. This is because if the force of mortality from causes other than overweight/obesity was to decline in the future, the mortality rate ratios for overweight and obesity would most certainly increase due to downward rescaling of the baseline risk. This phenomenon would in turn lead to higher aetiologic fractions which, although correctly applied to reduced numbers of total numbers of deaths from all causes, would result in similar numbers of deaths attributable to overweight/obesity as those reported here.

Whilst Scenario 3 was based on percentage reductions in prevalence cross-sectionally, the likelihood of whether these reductions are achievable was not assessed, and therefore could lead to limitations.

Our study is consistent with the evidence that there is an increased risk of death associated with overweight.[10] Other studies conducted in the U.K. and U.S. have also predicted increases in the future prevalence in overweight/obesity.[7 15] According to the U.K. *Foresight Report,* by 2035 the prevalence of obesity is expected to rise to 47% and 35% in men and women respectively and by 2050 over one half of the UK adult population could be obese (60% of men and 50% of women).[7] The U.S. report forecast that by as early as 2020, 77.6% of men would be overweight and 40.2% obese.[15] In women, the forecasts were 71.1% overweight and 43.3% obese.[15] Australia appears set to follow this worldwide increase in overweight and obesity prevalence,[1] unless effective interventions can be put in place as a matter of urgency.

There will be approximately 1.75 million deaths at ages 20+ years and 10.3 million PYLL at ages 20-74 years caused by overweight/obesity in Australia in 2011 to 2050 if current upward trends continue. Each Australian aged 20-74 years who dies from overweight/obesity in 2011 to 2050 will lose, on average 12 years of life before age 75 years. Scenarios 2, 3 and 4 indicate that if effective interventions are mounted, there are at least 0.5 million deaths and 2.3 million PYLL at ages 20-74 that can be prevented in 2011 to 2050. Therefore, there is evidently a huge burden associated with doing nothing at all and letting the current upward trends increase.

If further increases in overweight/obesity can be averted and prevalences stabilised at 2005 levels there will be approximately 1.25 million deaths at ages 20+ years and 8.0 million PYLL at ages 20-74 years caused by overweight and obesity in Australia in 2011 to 2050. This scenario highlights the benefit of merely abating the upward trends, underlined by the PYLL saved in males (1,497,252), females (816,574), and persons (2,313,826) at ages 20-74.

There is additional benefit from cross-sectional adult reductions evidenced by the three sections of Scenario 3. A 1% prevalence reduction would result in savings of 2,376,795 PYLL at ages 20-74. A 3% prevalence reduction would result in savings of 2,503,525 PYLL at ages 20-74 years. A 5% prevalence reduction would result in the most savings of 2,631,325 PYLL at ages 20-74. This indicates that approximately an additional 60,000 PYLL will be prevented with each additional 1% proportional reduction that can be achieved beyond a stabilisation at 2005 prevalences.

An effective intervention targeted only at Australian children will have approximately five times less beneficial impact on PYLL caused by overweight/obesity in 2011 to 2050 than an equivalently effective intervention targeted cross-sectionally at adults and children. The same intervention targeting only children will have approximately 30 times less beneficial impact on the number of deaths caused by overweight/obesity in 2011 to 2050 than an equivalently effective cross-section intervention. Targeting only children and waiting for them to grow up results in much slower progress, compared to targeting the whole population.

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