

# The health burden of preventable disease in Australia: a systematic review

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A large portion of non-communicable disease in Australia is due to risk factors that are largely preventable, such as tobacco use, alcohol consumption, high body mass index, physical inactivity and a poor diet. Around one-third of the health burden in Australia is attributable to modifiable risk factors.<sup>1</sup>

Lifestyle-related risk factors are highly prevalent in the Australian population. Tobacco use has declined over the past two decades, with fewer people taking up smoking, but this decline in current smokers plateaued between 2013 and 2016 with a current prevalence of 12%.<sup>1,2</sup> In 2014–15 17% of adults consumed on average more than two standard drinks per day, exceeding the lifetime risk guideline. Although this is less than the prevalence in 2004–05 of 22%, it demonstrates that a large number of Australians engage in risky alcohol consumption, with 15% of people having consumed over 10 standard drinks during a single drinking episode at least once in the previous 12 months.<sup>2,3</sup> Fifty-two per cent of adults are not sufficiently physically active. The vast majority of adults (95%) do not consume a sufficient amount of fruit and vegetables.<sup>2</sup> Two-thirds of Australian adults are overweight or obese with around one-quarter having a body mass index (BMI)  $\geq 30$  kg/m<sup>2</sup>.<sup>4</sup>

The consequences of chronic disease caused by these risk factors extends beyond the health of the individual to the costs of disease management incurred by the health care system, costs to non-health sectors of

## Abstract

**Objective:** A systematic review was conducted to determine the health burden of preventable disease in Australia.

**Methods:** The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement guidelines were followed to identify, screen and describe the protocols used in the systematic review.

**Results:** Eleven studies were included in the review. Data on the health burden associated with lifestyle-related risk factors were extracted by disease with outcomes reported in attributable number and proportion of deaths, years of life lost, years lived with disability and disability-adjusted life years (DALYs). Around one-third of DALYs was attributed to all modifiable risk factors. The range of estimates of DALYs attributable to each prioritised risk factor was: combined dietary risk factors, 7.2% to 9.7%; tobacco, 7.9% to 9.0%; alcohol, 5.1% to 12.2%; high body mass, 5.5% to 8.3%; and physical inactivity, 1.2% to 5.5%.

**Conclusions:** Although the methods used to estimate preventable health burden varied greatly between studies, all found that a substantial amount of death and disability was attributable to lifestyle-related risk factors.

**Implications for public health:** There is a large health burden in Australia caused by modifiable risk factors and further action is warranted to address this burden.

**Key words:** prevention, non-communicable disease, systematic review, burden of disease

governments (for example, law enforcement) and productivity impacts to businesses and households through reduced workplace productivity, home-based production and lost leisure time. Taking greater action on reducing the prevalence of lifestyle-related risk factors provides an opportunity to improve the health of the Australian population, reduce the burden on the health care system and enhance economic productivity.

To our knowledge, there is no systematic review of studies that have investigated the health burden of preventable disease in Australia. It would be useful to identify where

there is consistency in the estimates, where they differ, what methods have been used to calculate the estimates and the relative contribution of each risk factor to health burden. The aim of this systematic review was to establish the current state of the evidence on how much of the health burden in Australia is attributable to five lifestyle-related risk factors: tobacco use, alcohol consumption, physical inactivity, high body mass and an unhealthy diet.

It is worth noting the difference between 'attributable' and 'avoidable' burden. Attributable burden refers to the amount of disease present at a prevailing risk-factor

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level compared with the counterfactual of risk factors at their theoretical minimum, regardless of how achievable this level of prevalence is in reality. Avoidable burden refers to a comparison with a level of risk-factor exposure that could conceivably be achieved in practice, usually based on aspirational targets achieved in similar settings (known as Arcadian means) or the demonstrated effectiveness of prevention interventions. The purpose of this review was to establish the attributable health burden. The potential for policy to improve health is influenced by the actual effectiveness of prevention interventions, but burden of disease studies (and this review) provide a useful starting point for establishing the size of a problem, to document and encourage assessment of avoidable ill-health and health expenditure, and to motivate action towards finding and implementing cost-effective solutions.

## Methods

This systematic review aimed to answer the question: “What is the health burden of preventable disease in Australia?” A review protocol was developed by the project team to define the population, outcomes and study

types of interest. It also set out the inclusion and exclusion criteria, databases to be searched and key papers used to validate the search algorithms.

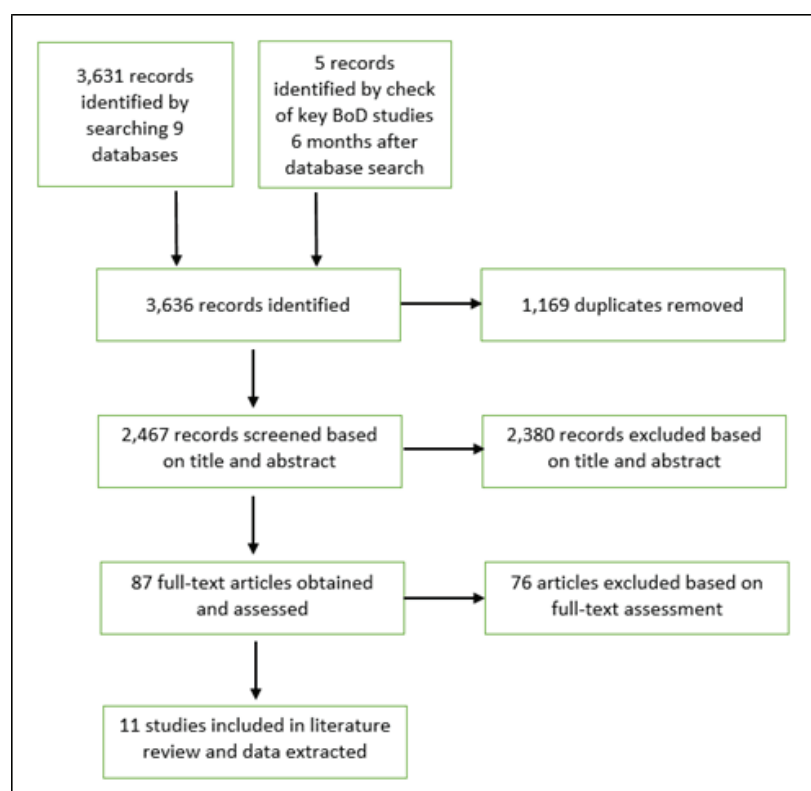
The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement guidelines were followed to identify, screen and describe the protocol used in the systematic review. Searches were conducted using the Medline Complete, Embase, Global Health, CINAHL Complete, Health Policy Reference Center, Informit (health subset), Cochrane Library and Joanna Briggs Institute databases. The Informit database was included so that grey literature specific to the Australian context was captured. In addition, an advanced Google search was conducted of .gov.au domains to capture relevant grey literature produced by the Australian Institute of Health and Welfare, the Australian Bureau of Statistics, the Productivity Commission and federal and state/territory health departments. The first 20 pages of Google results (200 items) were screened for relevant documents. The searches were conducted on 3 August 2017. The search algorithm was designed to be broad and included various permutations of the core topics (morbidity, mortality, premature, burden of disease,

risk attributable fractions, preventable and disease) and outcomes (quality adjusted life years, disability adjusted life years, deaths, years of life lost and years lived with disability) of interest. The searches were restricted to articles and reports published in the previous five years (1 January 2012 to 31 July 2017). This timeframe was chosen because we were interested in current estimates. The websites of key burden of disease studies identified in the review were checked six months after the initial search for updates in December 2017. References of included studies were manually searched to identify additional relevant studies. Full search algorithms for each database are provided in the online Supplementary File.

Duplicates were removed and title and abstracts were screened by a single author to determine their eligibility (see review flowchart, Figure 1). Full-text review of shortlisted papers was conducted by a single author with included and excluded studies reviewed by additional authors (JA and RC) with consensus achieved on the final list of included studies.

Five lifestyle-related risk factors were selected for detailed data extraction and reporting based on the stated priorities of The Australian Prevention Partnership Centre (TAPPC) that commissioned this work. Studies were eligible for inclusion if they examined at least one of the risk factors of interest (i.e. tobacco use, alcohol use, any dietary risk factor, physical inactivity and high body mass) and at least one of the outcomes of interest (deaths, years of life lost (YLLs), years lived with disability (YLDs), disability-adjusted life years (DALYs) and quality-adjusted life years (QALYs)). YLLs and YLDs are the two components used to calculate DALYs. The data on attributable burden for Australia was extracted from studies. Studies were included if they estimated the portion of preventable disease for Australia. Studies that estimated the preventable portion of disease due to risk factors that were not linked to behavioural factors, such as infectious diseases, social or environmental determinants of health, iatrogenic, and occupational risk factors only, were excluded. Non-English language articles were excluded. Quantifying the burden of disease was insufficient for inclusion; an estimate of the attributable portion of that burden was required. Where studies were part of a series produced by a single organisation, only the most recent version available at the

Figure 1: PRISMA flowchart summarising inclusion and exclusion process.



time was included in this review. Narrative reviews were checked for relevant articles.

Due to the diversity of methods and information sources used in the included studies, quantitative pooling of results in the form of meta-analysis was inappropriate. A narrative summary was prepared to summarise and report results.

## Results

### Search results

The systematic search identified 3,631 articles from nine databases and an additional five reports were identified as potentially relevant from the website search at six months post initial search (Figure 1). Titles and abstracts were screened and 87 articles were identified as potentially relevant. Full-text versions of these articles were reviewed against the criteria specified in the review protocol and 76 were subsequently excluded (reasons for exclusion are provided in supplementary material). Eleven unique studies were included in the review (Table 1).<sup>5-16</sup>

Three studies estimated the proportion of total health burden attributable to all modifiable risk factors.<sup>5,6,11</sup> The remaining eight studies estimated the health burden caused by a single risk factor or paired combinations of risk factors. Body mass index, tobacco use, insufficient dairy consumption and physical inactivity each had a single study that examined their impact.<sup>7,9,10,14</sup> Three studies estimated the health burden attributable to alcohol.<sup>12,15,16</sup> One study investigated the health burden of body mass index in combination with physical inactivity.<sup>8</sup>

Four studies examined different aspects of the Australian Burden of Disease Study 2011 (ABDS 2011).<sup>5-8</sup> The Global Burden of Disease Study 2016 (GBD 2016) estimated the health burden of the greatest number of modifiable risk factors.<sup>11</sup> Most studies (8 of 11) reported health burden in terms of the impact on DALYs attributable to a single, or a combination of, risk factors.<sup>5-12</sup> Three studies reported multiple outcomes including the attributable number of deaths, YLLs and YLDs.<sup>5,11,12</sup> Another three studies only reported the impact on deaths.<sup>14-16</sup> No studies reported attributable health burden in terms of quality-adjusted life years.

Figure 2 summarises the results of studies that reported the proportion of DALYs attributable to each of the five lifestyle-related risk factors.

### Multiple modifiable risk factors combined

Two studies estimated the health burden experienced by the entire Australian population due to all modifiable risk factors (Table 2). ABDS 2011 included 29 modifiable risk factors contributing to 188 risk-disease pairs and found that 44.3% of deaths (64,992 deaths), 43.2% of YLL (980,435 YLL), 19.5% of YLDs (434,632 YLDs) and 31.5% of all DALYs (1,414,978 DALYs) were attributable to these risk factors in the 2011 Australian population.<sup>5</sup> GBD 2016 included 84 risk factors and groups of risk factors contributing to 481 risk-outcome pairs and found that 54.5% of deaths (90,300), 51.3% of YLLs, 20.2% of YLDs and 35.8% of DALYs (1,935,000 DALYs) were attributable to all modifiable risk factors combined for the 2016 Australian population.<sup>11</sup>

### Diet

Two studies estimated the health burden for all Australians due to the joint effects of several dietary risk factors (Table 2). ABDS 2011 included 13 dietary risk factors but did not specify all diseases they were linked to.<sup>5</sup> It found that 12.1% of deaths (17,771 deaths), 11.3% YLLs (257,635 YLLs), 2.9% YLDs (65,128 YLDs) and 7.2% of all DALYs (322,763 DALYs) were attributed to dietary risk factors combined. GBD 2016 included 15 dietary risk factors linked to 49 diseases and found that 16.6% of deaths (27,500 deaths) and 7.9% of all DALYs (425,600 DALYs) were attributable to the joint effects of dietary risk factors.<sup>11</sup> A study that investigated diets low in dairy (funded by Dairy Australia) found that it was linked to six diseases and 75,012 DALYs.<sup>10</sup>

### Tobacco

Three studies estimated the health burden in Australia due to tobacco use (Table 2). ABDS 2011 linked tobacco use to 27 diseases and estimated it contributed to 12.8% of deaths (18,762 deaths), 13.5% of YLLs (306,208 YLLs), 4.3% of YLDs (96,170 YLDs) and 9% of DALYs (402,377 DALYs).<sup>5</sup> GBD 2016 linked tobacco use to a greater number of diseases (58) and estimated that it was associated with 13.4% of deaths (22,000) and 7.9% of DALYs (425,300).<sup>11</sup> Another recent study focused on Australian adults between the ages of 40 to 79 and estimated that tobacco use was linked to four diseases and caused 17.8% of deaths in males and 11.8% of deaths in females.<sup>14</sup>

### Alcohol

Five studies examined the health burden due to alcohol consumption (Table 2). ABDS 2011 included 27 diseases linked to alcohol and found that 4.5% of deaths (6,570), 6.1% of YLLs (139,608), 4% of YLDs (88,058) and 5.1% of DALYs (227,666) were due to alcohol consumption.<sup>5</sup> GBD 2016 included a greater number of diseases linked to alcohol and estimated it caused 4.9% of deaths (8,100) and 5.4% of DALYs (293,400).<sup>11</sup> Gao et al.<sup>12</sup> included 31 linked diseases and found that alcohol caused 4,558 deaths and 188,538 DALYs. Ogeil et al.<sup>16</sup> linked alcohol use to 42 diseases and found that it caused 4,613 deaths in people aged over 15 years. Shield et al.<sup>15</sup> found that alcohol caused 350 deaths related to breast cancer.

### Body mass

Three studies investigated the health burden for all Australians due to high body mass (Table 2). ABDS 2011 found that 19 diseases were linked to high body mass and caused 7.9% of deaths (11,564 deaths), 8.0% of YLLs (181,199 YLLs), 2.9% of YLDs (64,617 YLDs) and 5.5% of overall DALYs (245,816 DALYs).<sup>5</sup> This analysis was subsequently updated with new evidence and reported by socioeconomic status for the same 2011 reference year.<sup>7</sup> The lowest socioeconomic quartile experienced the highest burden linked to BMI (84,000 DALYs) and the highest socioeconomic quartile experienced the lowest burden linked to BMI (39,000 DALYs). Overall, the updated ABDS 2011 analysis found that 7% of all DALYs were associated with high BMI (312,500 DALYs). GBD 2016 included a greater number of diseases linked to high BMI (37) and found that 11% of deaths (18,200 deaths) and 8.3% of DALYs (447,800 DALYs) were due to high BMI.<sup>11</sup>

### Physical inactivity

Four studies estimated the health burden due to physical inactivity (Table 2). ABDS 2011 linked physical inactivity to five diseases and found that 7.8% of deaths (11,489), 7.8% of YLLs (177,106), 2.1% of YLDs (47,092) and 5% of DALYs (224,198) were due to physical inactivity. An updated analysis for ABDS 2011 increased the number of linked diseases to seven but revised down the estimate of overall DALYs attributable to physical inactivity to 2.6% (116,676). The revised, lower estimate was predominantly due to updated evidence on the strength of association

Table 1: Summary of included studies and methods.

Key characteristics				Mortality			Morbidity			Risk factors					Combined risk factor analysis
Study ID	Reference year	Major project series	Population groups	Attributable outcomes reported	Reference life table	Number of diseases or groups	Health states	Disability weight set	Comorbidity adjustment	Incidence or prevalence based DALYs	Number risk factors or groups	Risk factor list	Relative risks	TIMREDS	
AIHW 2016a <sup>5</sup> (ABDS 2011)	2011	ABDS 2011	All Australians	Deaths, YLLs, YLDs, DALYs	GBD 2010 standard aspirational life table	188	Adapted from GBD 2013	GBD 2013	GBD 2013 (independent multiplicative model)	prevalence	29	GBD 2010 plus sun exposure	GBD 2010, GBD 2013 and Taylor 2010	GBD 2010 except for sodium (expert advice) and low bone mineral density (GBD 2013)	50% attenuation for risks on the same causal pathway; product formula
AIHW 2016b <sup>6</sup> (ABDS 2011)	2011	ABDS 2011	Indigenous Australians	DALYs	GBD 2010 standard aspirational life table	188	Adapted from GBD 2013	GBD 2013	GBD 2013 (independent multiplicative model)	prevalence	29	GBD 2010, no sun exposure, add unimproved sanitation	GBD 2010, GBD 2013, Taylor 2010 and admin data	GBD 2010 except for sodium (expert advice) and low bone mineral density (GBD 2013)	50% attenuation for risks on the same causal pathway; product formula
AIHW 2017b <sup>7</sup> (ABDS 2011)	2011	ABDS 2011	All Australians	DALYs	GBD 2010 standard aspirational life table	22	Adapted from GBD 2013	GBD 2013	GBD 2013 (independent multiplicative model)	prevalence	1 (BMI)	not applicable	GBD 2015 and selected studies	GBD 2015 (BMI 20 to 25)	not applicable
AIHW 2017a <sup>8</sup> (ABDS 2011)	2011	ABDS 2011	All Australians	DALYs	GBD 2010 standard aspirational life table	7	Adapted from GBD 2013	GBD 2013	GBD 2013 (independent multiplicative model)	prevalence	2 (physical inactivity alone and combined with obesity)	not applicable	GBD 2015	GBD 2015 (high level of physical activity)	Product formula
Ding 2016 <sup>9</sup>	2013	-	All Australians	DALYs	GBD 2013 standard aspirational life table	5	GBD 2013	GBD 2013	GBD 2013 (independent multiplicative model)	prevalence	1 (physical inactivity)	not applicable	Lee 2012, Wendel-Vos 2004 for stroke	WHO recommendations	not applicable
Doidge 2012 <sup>10</sup>	2010-11	-	All Australians	DALYs	not reported	6	not reported	not reported	not reported	not reported	1 (insufficient dairy)	not applicable	de novo lit review, informed by single studies or meta-analyses	not reported	not reported
Gakidou 2017 <sup>11</sup> (GBD 2016)	2016	GBD 2016	All Australians	Deaths, YLLs, YLDs, DALYs	GBD 2016 standard aspirational life table	481 risk-outcome pairs	GBD 2013 (235 health states)	GBD 2013	GBD 2015 (simulated multiplicative function)	prevalence	84	GBD 2016	GBD 2016	GBD 2016	Product formula and attenuation matrix for each pairing
Gao 2014 <sup>12</sup>	2010	-	Australians aged 15+	Deaths, YLLs, YLDs, DALYs	GBD 2010 standard aspirational life table	31	GBD 2010	GBD 2010	GBD 2010	prevalence	1 (Alcohol)	not applicable	Various meta-analyses	Lifetime abstainer	not applicable
Ogeil 2016 <sup>16</sup>	2010	-	Australians aged 15+	Deaths	not applicable	42	not applicable	not applicable	not applicable	not applicable	1 (Alcohol)	not applicable	GBD 2010	not reported	not applicable
Renteria 2016 <sup>14</sup>	2000-10	-	Adults 40 to 79 years	Deaths	not applicable	4	not applicable	not applicable	not applicable	not applicable	1 (Tobacco)	not applicable	Cancer prevention study	not smoking	not applicable
Shield 2016 <sup>15</sup>	2012	-	Women	Deaths, incidence	not applicable	1	not applicable	not applicable	not applicable	not applicable	1 (Alcohol)	single meta-analysis	single meta-analysis	Lifetime abstainer	not applicable

Table 2: Summary of attributable health burden reported by included studies.

Study ID	Population group	Number of risk factors	Fatal burden			Non-fatal burden			Total burden	
			Deaths	Deaths (%)	YLL	YLL (%)	YLD	YLD (%)	DALYs	DALYs (%)
All modifiable risk factors										
AIHW 2016a <sup>5</sup> (ABDS 2011)	All Australians	29	64,992	44.3%	980,435	43.2%	434,632	19.5%	1,414,978	31.5%
AIHW 2016b <sup>6</sup> (ABDS 2011)	Indigenous Australians	29	-	-	-	-	-	-	-	36.9%
Gakidou 2017 <sup>11*</sup> (GBD 2016)	All Australians	84	90,300 (84,300–96,600)	54.5% (52.0%–56.8%)	-	51.3% (49.5%–53.0%)	-	20.2% (18.7%–21.7%)	1,935,000 (1,747,500–2,147,700)	35.8% (33.2%–38.6%)
Tobacco										
AIHW 2016a <sup>5</sup> (ABDS 2011)	All Australians	27	18,762	12.8%	306,208	13.5%	96,170	4.3%	402,377	9.0%
AIHW 2016b <sup>6</sup> (ABDS 2011)	Indigenous Australians	27	-	-	-	-	-	-	23,381	12.3%
Gakidou 2017 <sup>11*</sup> (GBD 2016)	All Australians	58	22,200 (20,200–24,600)	13.4% (12.5%–14.4%)	-	-	-	-	425,300 (386,700–467,600)	7.9% (6.9%–9.0%)
Renteria 2016 <sup>14~</sup>	Males 40 to 79 years	4	-	17.8% (17.3%–19.5%)	-	-	-	-	-	-
	Females 40 to 79 years	4	-	11.8% (10.5%–12.6%)	-	-	-	-	-	-
Alcohol										
AIHW 2016a <sup>5</sup> (ABDS 2011)	All Australians	27	6,570	4.5%	139,608	6.1%	88,058	4.0%	227,666	5.1%
AIHW 2016b <sup>6</sup> (ABDS 2011)	Indigenous Australians	27	-	-	-	-	-	-	15,850	8.3%
Gakidou 2017 <sup>11*</sup> (GBD 2016)	All Australians	39	8,100 (4,400–12,300)	4.9% (2.7%–7.3%)	-	-	-	-	293,400 (215,500–373,600)	5.4% (4.0%–6.9%)
Gao 2014 <sup>12</sup>	Australians 15+	31	4,558	-	120,168	10.9%	68,370	15.4%	188,538	12.2%
Ogeil 2016 <sup>16</sup>	Australians aged 15+	42	4,613	-	-	-	-	-	-	-
Shield 2016 <sup>15</sup>	All Australians	1	350	12.0%	-	-	-	-	-	-
Physical inactivity										
AIHW 2016a <sup>5</sup> (ABDS 2011)	All Australians	5	11,489	7.8%	177,106	7.8%	47,092	2.1%	224,198	5.0%
AIHW 2016b <sup>6</sup> (ABDS 2011)	Indigenous Australians	5	-	-	-	-	-	-	10,504	5.5%
AIHW 2017a <sup>8</sup> (ABDS 2011)	Socioeconomic group Q1 (lowest)	7	-	-	-	-	-	-	30,000	-
	Socioeconomic group Q2	7	-	-	-	-	-	-	26,000	-
	Socioeconomic group Q3	7	-	-	-	-	-	-	23,000	-
	Socioeconomic group Q4	7	-	-	-	-	-	-	20,000	-
	Socioeconomic group Q5 (highest)	7	-	-	-	-	-	-	19,000	-
	Total	7	-	-	-	-	-	-	116,676	2.6%
Ding 2016 <sup>9^</sup>	All Australians	5	-	6.4% (1.2%–14.0%)	-	-	-	-	38,900 (4,900–112,300)	-
Gakidou 2017 <sup>11*</sup> (GBD 2016)	All Australians	5	5,200 (2,800–7,800)	3.1% (1.7%–4.7%)	-	-	-	-	65,300 (36,000–96,100)	1.2% (0.7%–1.8%)
High body mass										
AIHW 2016a <sup>5</sup> (ABDS 2011)	All Australians	19	11,564	7.9%	181,199	8.0%	64,617	2.9%	245,816	5.5%
AIHW 2016b <sup>6</sup> (ABDS 2011)	Indigenous Australians	19	-	-	-	-	-	-	15,647	8.2%
AIHW 2017b <sup>7</sup> (ABDS 2011)	Socioeconomic group Q1 (lowest)	22	-	-	-	-	-	-	84,000	7.9%
	Socioeconomic group Q2	22	-	-	-	-	-	-	71,000	6.9%
	Socioeconomic group Q3	22	-	-	-	-	-	-	60,000	6.5%
	Socioeconomic group Q4 (highest)	22	-	-	-	-	-	-	39,000	5.5%
	Total	22	-	-	-	-	-	-	312,505	7.0%
Gakidou 2017 <sup>11*</sup> (GBD 2016)	All Australians	37	18,200 (11,400–25,100)	11.0% (6.9%–15.1%)	-	-	-	-	447,800 (302,200–608,600)	8.3% (5.8%–10.8%)
Diet										
AIHW 2016a <sup>5</sup> (ABDS 2011)	All Australians	All dietary risk factors	17,771	12.1%	257,635	11.3%	65,128	2.9%	322,763	7.2%
AIHW 2016b <sup>6</sup> (ABDS 2011)	Indigenous Australians	All dietary risk factors	-	-	-	-	-	-	18,400	9.7%
Doidge 2012 <sup>10</sup>	All Australians	Diet low in dairy	-	-	-	-	-	-	75,012	-
Gakidou 2017 <sup>11*</sup> (GBD 2016)	All Australians	All dietary risk factors	27,500 (23,100–32,300)	16.6% (14.2%–19.3%)	-	-	-	-	425,600 (364,300–497,100)	7.9% (6.6%–9.4%)

## Notes:

The estimates for 'all modifiable risk factors' includes risk factors such as environmental factors, occupational factors and infectious agents.

If confidence intervals are not reported in this table, they were not reported by the study.

~: indicates the outcome measure was not reported by the study.

\*: Figures in parenthesis are 95% uncertainty intervals.

^: Figures in parenthesis are 95% confidence intervals.

~: Figures in parenthesis are 95% uncertainty intervals.

Acronyms: AIHW - Australian Institute of Health and Welfare; YLL - years of life lost; YLD - years lived in disability; DALY - disability adjusted life year; ABDS - Australian Burden of Disease Study series; GBD - Global Burden of Disease study series.



between physical inactivity and a number of diseases. This updated analysis reported results by socioeconomic status with the lowest socioeconomic quintile incurring the highest number of DALYs (30,000) compared with the highest socioeconomic quintile (19,000). As part of an analysis of the global economic impact of physical inactivity, Ding et al.<sup>9</sup> estimated that it caused 6.4% of deaths and 38,900 DALYs in Australia. GBD 2016 linked physical inactivity to five diseases and found that it contributed to 3.1% of deaths (5,200) and 1.2% of overall DALYs (65,300).

### Indigenous Australians

There are 798,400 Aboriginal and Torres Strait Islander people in Australia (3.3% of the total Australian population).<sup>17</sup> The preventable burden of disease experienced by Indigenous Australians was investigated by a single study.<sup>6</sup> The sub-study of ABDs 2011 found that all modifiable risk factors combined were associated with 36.9% of DALYs, tobacco use 12.3% of DALYs, alcohol consumption 8.3% of DALYs, physical inactivity 5.5% of DALYs, high BMI 8.2% of DALYs, and dietary factors 9.7%; all higher than the Australian population as a whole. Indigenous Australians experience death and disability as measured by the DALY at a rate that is 2.3 times the non-Indigenous population.<sup>6</sup> Although the selected risk factors occur with a slightly higher prevalence in the Indigenous population, they only account for a portion of the health gap between Indigenous and non-Indigenous Australians.<sup>6</sup> Most of the health gap between Indigenous Australians and the non-Indigenous population is due to issues other than these five lifestyle-related risk factors, such as social determinants of health.

### Methods adopted by included studies

A variety of methods were adopted for each study (Table 1). A reference life table is required when calculating DALYs based on YLLs and YLDs and all studies (where this was reported) used the Global Burden of Disease study standard aspirational life table. Most of the differences in estimates between included studies were explained by the number of risk-disease pairs used to estimate the burden of each risk factor and the strength of the associations. This reflects both evolving evidence on the association between risk factors and diseases (due to the evidence available in the year of publication) and choices made by analysts when deciding which risks and diseases to include in their study. For example, Australian Institute of Health and Welfare's (AIHW) update on the health burden of physical inactivity included dementia and uterine cancer based on advice from experts and their review of the literature, whereas the GBD 2016 study did not link these two diseases to physical inactivity based on their assessment of whether they met the World Cancer Research Fund grades of convincing or probable evidence.<sup>8,11</sup>

The sources of relative risks, which determine the strength of association between risk factors and the diseases they cause, varied greatly between studies ranging from de-novo systematic reviews with meta-analysis,<sup>11</sup> non-systematic literature reviews<sup>8</sup> and original data analysis.<sup>14</sup> Defining health states and their associated disability weights is required to calculate YLDs. All studies adopted disability weights set by the Global Burden of Disease Study (GBD) 2013<sup>18</sup> except for the study on alcohol by Gao et al.<sup>12</sup> which used an earlier version of GBD disability

weights. When calculating YLDs, analysts have a choice of whether to estimate this for a particular year based on the prevalence of a disease during that year or the incident cases that occurred that year. All studies where DALYs were calculated adopted the prevalence method of calculating YLDs (i.e. for all cases rather than just new cases).

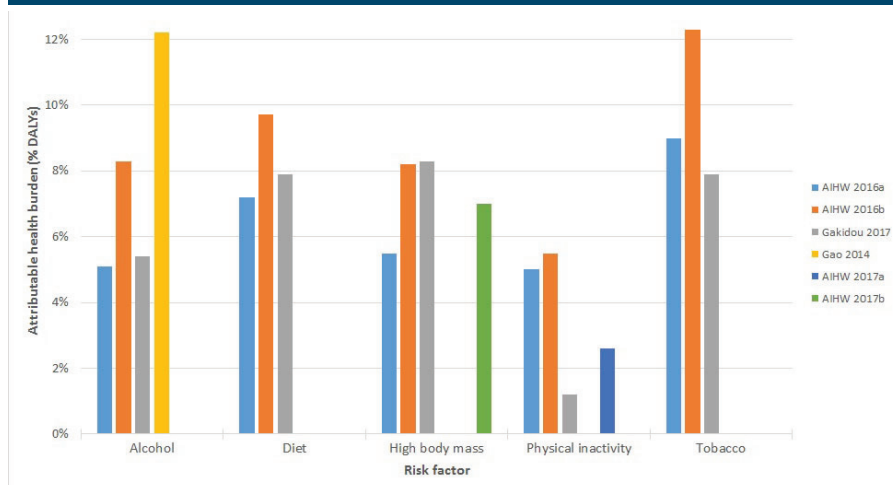
Theoretical Minimum Risk Exposure Levels (TMREs) represent the lowest prevalence of a risk factor that could exist in a population (for example, the whole population as 'never smokers'). This is required to estimate the preventable portion of disease associated with each risk factor. Where studies examined multiple risk factors, TMREs were sourced from the last GBD study available at the time. Where studies examined a single risk factor, TMREs were often self-evident, such as all people being non-smokers or having a BMI below 25. In four studies, stochastic variation was built into input parameter estimation allowing uncertainty intervals to be calculated around estimated results.<sup>9,11,14,16</sup>

### Discussion

Although the methods used to estimate preventable health burden varied, all found that a substantial amount of death and disability was attributable to lifestyle-related risk factors. For example, tobacco use, high BMI and an unhealthy diet were each associated with at least 17,000 deaths in the year under study. Alcohol consumption and physical inactivity contributed to at least 5.1% and 1.2% of DALYs experienced by the Australian population in a year. There was a higher prevalence of these risk factors among Indigenous Australians, who also experienced higher disease prevalence compared with the overall Australian population.

Of the five lifestyle-related risk factors, an unhealthy diet accounted for the greatest number of preventable deaths in Australia (27,500) according to the GBD 2016. This burden was driven by the high prevalence of unhealthy diets and spread unevenly across the 15 individual dietary risk factors, with the greatest number of deaths attributable to diets low in fruit (5,500), vegetables (4,400), whole grains (7,400), and nuts and seeds (4,900). This highlights the importance of implementing interventions that impact the food environment as a whole in Australia, rather than a single nutritional element, as well as the impact of under-nutrition in addition to overweight and obesity.

Figure 2: Attributable health burden for Australia by risk factor and study.



Tobacco use was associated with a variety of cancers and accounts for over half of all DALYs due to lip and oral cavity cancer, nasopharynx cancer, oesophageal cancer, and around three quarters of larynx cancer and tracheal, bronchus and lung cancer.<sup>11</sup> Smoking contributed to most of the burden related to chronic obstructive pulmonary disease with estimates ranging from 70% to 75%.<sup>5,11</sup> GBD 2016 included a protective association of smoking with Parkinson's disease but ABDS 2011 did not. This averted disease was clearly outweighed by the health burden caused by other smoking-related disease. Although public health measures have worked to reduce the burden of tobacco in Australia, further interventions are warranted to help greater numbers of people quit smoking.

The included studies linked alcohol consumption to alcohol use disorders, suicide and self-inflicted injuries, coronary heart disease, road traffic accidents and stroke. A slight protective effect conveyed through a reduction in deaths related to ischaemic heart disease and diabetes was included in both the GBD 2016 and the study by Ogeil et al.<sup>16</sup> but this was outweighed by the health burden caused by other diseases. A limitation to concluding that alcohol provides a protective effect for ischaemic heart disease and diabetes is that GBD 2016 defined the alcohol consumption risk factor as grams per day consumed over a 12-month period.<sup>11</sup> Excessive or episodic binge drinking may be positively associated with ischaemic heart disease (adverse health consequences) and this protective effect was omitted for binge drinkers by Ogeil et al.<sup>16</sup> The negative overall health consequences have recently been confirmed at any level of alcohol consumption.<sup>19</sup>

The health burden of physical inactivity had the greatest variation of estimates of the prioritised risk factors with more recent estimates reducing the attributable burden. The ABDS 2011 found that physical inactivity contributes to 11,489 (7.8%) deaths and 224,198 DALYs, or 5% of the overall health burden.<sup>5</sup> However, this was revised down to 2.6% of the overall DALY burden (still for the 2011 population; deaths not reported separately).<sup>8</sup> The recent lower estimates of health burden were mainly due to newer data showing a weaker association between physical inactivity and linked diseases. The health burden was still large in absolute terms despite the most recent estimates being lower than previous estimates. The GBD 2016

found that physical inactivity contributed to 65,300 DALYs compared with a much higher estimate by ABDS 2011 (updated estimate) of 116,676 DALYs.<sup>7,11</sup> Both studies included an association between physical inactivity and coronary heart disease, type 2 diabetes, bowel cancer, ischaemic heart disease and breast cancer. The differences in results may be driven by the inclusion of dementia and uterine cancer in ABDS 2011. Ding et al.<sup>9</sup> reported the lowest estimate of attributable burden (38,900 DALYs). This was most likely due to a definition of sufficient physical activity as 150 minutes of moderate or vigorous exercise per week. This roughly equates to 750 to 1,050 MET (metabolic equivalent of task) minutes per week and contrasts with the definition of sufficient physical activity used by GBD 2016 of 3,000 to 4,500 MET minutes per week.<sup>11</sup> A lower prevalence of physical inactivity results in lower population attributable fractions. The lower estimate by Ding et al.<sup>9</sup> was also influenced by relative risks sourced from older meta-analyses published in 2012<sup>20</sup> and 2004,<sup>21</sup> which contrasts with GBD 2016 that was informed by a 2016 meta-analysis<sup>22</sup>.

The AIHW also released revised estimates for the burden of disease associated with elevated BMI, increasing the estimate of DALYs attributable to this risk factor from 5.5% in 2016 to 7% in 2017. This was mainly due to adjustments to the TMRELS, updating relative risks for breast cancer, musculoskeletal conditions and oesophageal cancer, and the addition of another eight linked diseases. The GBD 2016 study found a greater health burden related to high BMI accounting for 11% of all deaths (18,200) and 8.3% of all DALYs. This study included 37 linked diseases compared with 22 from AIHW.

Numerous effective and cost-effective interventions are available to policy makers in Australia to reduce the prevalence of lifestyle-related risk factors.<sup>23-26</sup> Recent research highlights specific policy gaps where governments,<sup>27</sup> supermarkets,<sup>28</sup> food and beverage manufacturers<sup>29</sup> and quick-service restaurants<sup>30</sup> have an opportunity to improve the food environment of the Australian population. Another program of priority-setting studies evaluated the economic credentials of sixteen diverse obesity prevention policies across multiple sectors and areas of governance, and found that all were either dominant (improving health benefits as well as being cost-saving) or cost-effective (providing an improvement in

health benefits that outweighed an increase in costs).<sup>31</sup> The benefits of these interventions can extend beyond the current population and have a positive intergenerational impact. Despite this, many solutions remain unimplemented and only the equivalent of 1.34% of the health care budget is allocated to prevention activities.<sup>32</sup> This is lower than similar health care systems such as in the United Kingdom, Canada and New Zealand.<sup>32</sup>

There are a number of limitations to this study. First, it was restricted to reports published in the past five years. Although this may have missed older studies focusing on specific risk factors, contemporary estimates of attributable burden are more relevant to current policy development and investment decisions. Second, a single author screened and selected studies for inclusion due to time and resource constraints. There is a risk this may have reduced the sensitivity of the screening process. However, two additional authors checked the inclusion and exclusion of full-text papers. The data extracted on specific risk factors was restricted to five modifiable risks commonly considered to be related to lifestyle choices for the sake of making reported results tractable. As a result, other important risk factors that contribute to substantial amounts of health burden, such as high blood pressure and high cholesterol, were not treated separately in this paper. They are included in data provided for overall estimates of health burden related to all modifiable risk factors (Table 2). Although the results of included studies are not directly comparable due to the variation in methods used, this review provides a useful, systematic summary of recent studies on the degree of preventable health burden in Australia.

## Conclusion

Despite the impacts of public health interventions on reducing the prevalence of some modifiable risk factors, preventable disease still accounts for one-third of the health burden in Australia. An unhealthy diet, tobacco use and alcohol consumption are the biggest contributors to preventable disease based on overall impact on DALYs. A number of interventions that have been shown to be effective and cost-effective are available to policy makers. Further evidence on the effectiveness and cost-effectiveness of additional interventions, particularly those that target multiple risk factors concurrently, would be a useful addition to this evidence-base.

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## Supporting Information

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

**Supplementary File 1:** Search strategies, detailed results tables and excluded studies.