The economic cost of preventable disease in Australia: a systematic review of estimates and methods

Paul Crosland,[1,2] Jaithri Ananthapavan,[1-3] Jacqueline Davison,[2,4] Michael Lambert,[2,5] Rob Carter[1,2]

Abstract

Objective: The aim of this literature review was to establish the economic burden of preventable disease in Australia in terms of attributable health care costs, other costs to government and reduced productivity.

Methods: A systematic review was conducted to establish the economic cost of preventable disease in Australia and ascertain the methods used to derive these estimates. Nine databases and the grey literature were searched, limited to the past 10 years, and the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines were followed to identify, screen and report on eligible studies.

Results: Eighteen studies were included. There were at least three studies examining the attributable costs and economic impact for each risk factor. The greatest costs were related to the productivity impacts of preventable risk factors. Estimates of the annual productivity loss that could be attributed to individual risk factors were between $840 million and $14.9 billion for obesity; up to $10.5 billion due to tobacco; between $1.1 billion and $6.8 billion for excess alcohol consumption; up to $15.6 billion due to physical inactivity and $561 million for individual dietary risk factors. Productivity impacts were included in 15 studies and the human capital approach was the method most often employed (14 studies) to calculate this.

Conclusions: Substantial economic burden is caused by lifestyle-related risk factors.

Implications for public health: The significant economic burden associated with preventable disease provides an economic rationale for action to reduce the prevalence of lifestyle-related risk factors. New analysis of the economic burden of multiple risk factors concurrently is needed.

Key words: burden of disease, health economics, lifestyle-related risk factors, non-communicable disease, prevention

The authors of the Global Burden of Disease study found that 36% of the health burden in Australia in 2016 was attributable to modifiable risk factors.[1] Many of these risk factors are lifestyle-related, such as tobacco smoking, alcohol consumption, an unhealthy diet, physical inactivity and obesity.[2] Crosland et al., in a recent systematic review, identified multiple studies that quantified the health burden of lifestyle-related risk factors.[3] In addition to the substantial health burden, preventable diseases also have a significant economic impact. The cost of identifying, diagnosing, managing and providing ongoing surveillance of disease caused by modifiable risk factors is incurred by all aspects of the healthcare system. Preventable disease is also associated with costs to government outside the healthcare sector, such as the criminal justice system for alcohol-related violence and accidents, and reduced taxation receipts to governments due to reduced productivity. Businesses, individuals and the broader economy suffer when people are unable to work temporarily, due to short-term illness, or permanently, because of premature retirement or mortality. These economic costs are important considerations for decision-makers when policy priorities are set, and resources are allocated to improve society's welfare.

The purpose of this review was to establish the current state of the evidence on the economic impact of preventable disease in Australia, identify gaps in that evidence and summarise the methods that have been used. The aim was to answer the question: *What is the economic cost of preventable disease in Australia and what methods are used to make these estimates?*

A variety of methods are available to analysts when estimating the economic impact of preventable disease and these choices influence the results of the analysis. Key design aspects of an economic analysis that affect these estimates are study perspective, reference year, country/currency, discount

1. Deakin University, Geelong, Deakin Health Economics, Institute for Health Transformation, Faculty of Health, Victoria
2. The Australian Prevention Partnership Centre, Sax Institute, New South Wales
3. Global Obesity Centre (GLOBE), Institute for Health Transformation, Faculty of Health, Deakin University, Victoria
4. Decision Analytics, Sax Institute, New South Wales
5. Sax Institute, New South Wales
Correspondence to: Mr Paul Crosland, Deakin Health Economics, Institute for Health Transformation, Deakin University, 221 Burwood Highway, Burwood, Victoria 3125; e-mail: paul.crosland@deakin.edu.au
Submitted: March 2019; Revision requested: May 2019; Accepted: June 2019
The authors have stated they have no conflict of interest.

Aust NZ J Public Health. 2019; Online; doi: 10.1111/1753-6405.12925

rate, apportionment of costs to a risk factor, timeframe and distinguishing between attributable and avoidable burden.[1,4,5] Descriptions of each of these aspects have been provided in the Supplementary File.

Methods

A review protocol was developed by the project team to guide the systematic review process, which included definitions for the population, outcomes, study types of interest, databases to be searched and the inclusion and exclusion criteria. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement guidelines were followed to identify, screen and report results of the review. Searches were conducted using the MEDLINE Complete, Econlit, Global Health, CINAHL Complete, Health Policy Reference Center, Embase, Informit, and the 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 of '.gov.au' domains was executed to capture relevant grey literature produced by and for the Australian Institute of Health and Welfare, the Australian Bureau of Statistics, the Productivity Commission and federal and state/territory health departments, including VicHealth. The first 20 pages (200 entries) of Google results were screened for relevant documents. The searches were conducted on 11 January 2018.

The search algorithms used broad permutations of terminology describing the risk factors of interest (tobacco smoking, alcohol use, diet, overweight and obesity, and physical inactivity) and outcomes of interest (attributable cost, economic burden, prevention). These five lifestyle-related risk factors were selected based on the priorities of The Australian Prevention Partnership Centre who commissioned this work.[6] Four of these are also ranked in the top six risk factors of attributable health burden according to the Global Burden of Disease Study 2017, with low physical activity ranked 14th.[7] The National Health Service Economic Evaluation Database economic study filters designed by the National Institute for Health Research Centre for Reviews and Dissemination were used to isolate economic analyses.[8] Date of publication was restricted to the past ten years (January 2008 to December 2017) because we were interested in the most current data available. References of included studies were manually searched to identify additional relevant studies. The full search algorithms are available in the Supplementary File.

Studies were included if they estimated the costs attributable to at least one of the lifestyle-related risk factors (tobacco smoking, alcohol use, diet, overweight and obesity, and physical inactivity) for Australia or one of its states or territories. Outcomes of interest included health sector expenditure on treating and managing preventable disease, productivity losses in terms of workforce production, household production and leisure time, and monetised representations of healthy years of life lost. Articles written in the English language only were included. All study designs were considered; however, cost-effectiveness analyses of specific prevention interventions were excluded because this review focused on the total economic cost of preventable disease, rather than the value for money of specific prevention interventions. Conference abstracts were also excluded due to the lack of reported detail on methods and results. Duplicates were removed and title and abstracts screened by a single author (PC) to determine eligibility. Full-text review of shortlisted papers was conducted by a single author (PC), with included and excluded studies reviewed by additional authors (JA and RC), with consensus achieved on the final list of included studies (all authors).

Quantitative synthesis of results could not be carried out due the variation in methods, definitions of risk factors, and outcomes used in included studies. Therefore, a narrative review was prepared. Data were extracted on the main methods reported, economic burden of risk factors and results of scenario analyses. The main methodological approaches and design features that may impact economic burden estimates such as study perspective, reference year, country/currency, discount rate, apportionment of costs to a risk factor and timeframe were extracted from included studies to inform comparison between studies. Descriptions of each of these methodological features and how they may impact the results has been provided in the Supplementary File.

All monetary values provided in the results tables were indexed to 2016–17 Australian dollars. The Australian dollar was used for all studies except for one that conducted calculations based on international dollars.[9] An international dollar would buy in the specified country a comparable amount of goods and services a US dollar would buy in the US.[10] The results relating to Australia from this study were converted to Australian dollars using the World Bank's purchasing power parity conversion factor for 2013 (the cost year for the study) and then indexed to 2016–17 Australian dollars. Healthcare costs from all studies were indexed to 2016–17 using the Australian Institute of Health and Welfare's (AIHW) total health price index.[11] All other monetary estimates were inflated to 2016–17 values using the Gross National Expenditure Implicit Price Deflator from the Australian Bureau of Statistics.[12]

Results

Search results

We identified 6,986 records with the systematic search using the nine databases and an additional 16 records by manually checking references of other included studies. A total of 1,477 duplicates were removed and 5,467 records were excluded based on title and abstract. Fifty-eight full-text articles and reports were obtained and reviewed. Thirty-three papers were excluded on assessment of the full-text versions based on the inclusion and exclusion criteria specified in the review protocol. Approximately half of the full-text papers were excluded because they did not provide a cost estimate of the preventable portion of total costs. Other reasons for excluding full-text papers were not providing population-level estimates and the type of analysis being a cost-effectiveness analysis of a specific intervention. Twenty-five articles or reports were subsequently included with 11 of these relating to four unique underlying studies. Therefore, 18 unique studies were included in the literature review.[9,13-36] Figure 1 summarises the screening process and the number of papers that were included and excluded at each stage. A list of studies excluded on assessment of full papers is provided in the Supplementary File.

Given that there may be several publications related to a single underlying study, a greater number of references appear than the number of studies referred to in subsequent text. Authors of twelve studies estimated the total economic burden attributed to a risk factor or multiple risk factors.[9,13,18,23-26,29-32,35,36] Authors of one study conducted scenario modelling to estimate the economic benefits of reducing the prevalence of risk factors.[14] Authors of five studies incorporated both estimates of total economic burden and scenario modelling of potential benefits of reducing the prevalence of risk factors.[15-17,19-22,27,28,33,34] Nine (of 25) publications were published in peer-reviewed journals[9,14,16-18,23,27,28,35] with the remainder published by the organisation that conducted the research (grey literature)[13,15,19-22,24-26,29-34,36] for the purposes of informing a government entity,[15,19-21,29,32,36] non-government advocacy organisation[13,26,33,34] or commercial enterprise.[22,25,30,31]

Table 1 contains a list of the studies and the main methodological approaches adopted by the analysts. The headline estimates of total economic impact and attributable health burden are provided in Table 2. Table 3 reports a list of the studies that conducted scenario modelling and the range of estimates of the benefits predicted under those different scenarios.

Multiple risk factors

Authors of two studies examined the total economic impact attributable to multiple risk factors (Table 2);[15-17,19,27,28] however, none of them looked exclusively at the five risk factors of interest in this review. Cadilhac et al. calculated the lifetime economic impact for the 2008 Australian population caused by six risk factors, including the five risk factors of interest (long-term, high-risk alcohol consumption; high body mass index [BMI >25kg/m^2]; inadequate fruit and vegetable consumption; physical inactivity; and tobacco smoking) and the addition of high psychological distress caused by intimate partner violence.[15,17] The authors found the cost of all six risk factors combined was $6.3 billion in healthcare costs, $90.5 million in other costs to government (lost taxation revenue) and $8.1 billion in productivity losses over the lifetime of the 2008 Australian population. These risk factors were also estimated to cause 26,000 deaths and 414,000 disability-adjusted life years (DALYs; a measure that combines both fatal and non-fatal health burden by adding the years of life lost due to premature death with years lived with illness by assigning different weights to different diseases)[37,38] in the same population. Collins and Lapsley analysed the annual costs associated with alcohol misuse and tobacco smoking for the Australian population in 2005; however, their estimates also included the impact of illicit drugs.[19] They estimated that annual healthcare costs attributable to these risk factors was $3.2 billion, other costs to government (for example, police and criminal courts) were $4.8 billion, productivity losses were $16.9 billion and the monetised value of health lost was $31.8 billion.

Cadilhac et al. conducted a scenario analysis of reducing multiple risk factors concurrently based on Arcadian means (aspirational reductions in risk factor prevalence, usually based on reductions achieved in comparable populations elsewhere) (Table 3).[15,17] Cadilhac et al. estimated lifetime economic benefits for the 2008 Australian population based on a 3% reduction in the prevalence of high BMI (a decrease from 27% to 24% in prevalence of obesity); 8% reduction in the prevalence of tobacco smoking (a decrease from 23% to 15% in prevalence of current smokers); a 35% reduction in the per capita consumption of alcohol (down to 6.4 litres from 9.8 litres consumed per year); a 10% decrease in adults who were sedentary or have a low activity level (from 70% to 60%); an increase of 34% in the amount of fruit and vegetables consumed (approximately two additional serves of vegetables or one piece of fruit per day, from 503 grams to 675 grams of fruit and vegetables per day); and a 5% reduction in prevalence of intimate partner violence. This resulted in $1.78 billion of healthcare cost savings; $1.86 billion in production improvements; and a relatively small $26 million increase in non-healthcare costs to government over the lifetime of the 2008 Australian population. This counterintuitive increase in non-healthcare costs was due to taxation revenue forgone and is discussed in the section on alcohol consumption.[15,17] This ideal scenario of multiple risk factor reduction estimated that 6,000 deaths and 95,000 DALYs would be averted. An alternative scenario analysis was conducted based on half the reduction in risk factor prevalence compared with the Arcadian means. This resulted in approximately half the benefits anticipated by the ideal scenario analysis.

Overweight and obesity

The largest number of studies investigating the economic cost attributable to a single risk factor was for overweight and obesity. Four studies focused on obesity only (BMI > 30kg/m^2)[13,24,25,33,34] with another three including overweight (BMI > 25 kg/m^2) as a risk factor[15,17,18,36] (Table 2). Studies that contained estimates of attributable annual health service costs due to obesity reported estimates ranging from $1.5 billion to $4.6 billion.[13,24,25,31,33,34] The diseases with the highest costs to the healthcare system related to overweight and obesity were generally osteoarthritis, type 2 diabetes and cardiovascular disease. The categories of health expenditure were mostly due to pharmaceuticals and hospital care. The studies that investigated costs to government not related directly to healthcare expenditure tended to focus on the revenue impacts of income tax and company tax

Figure 1: PRISMA diagram, flowchart of inclusion and exclusion process.

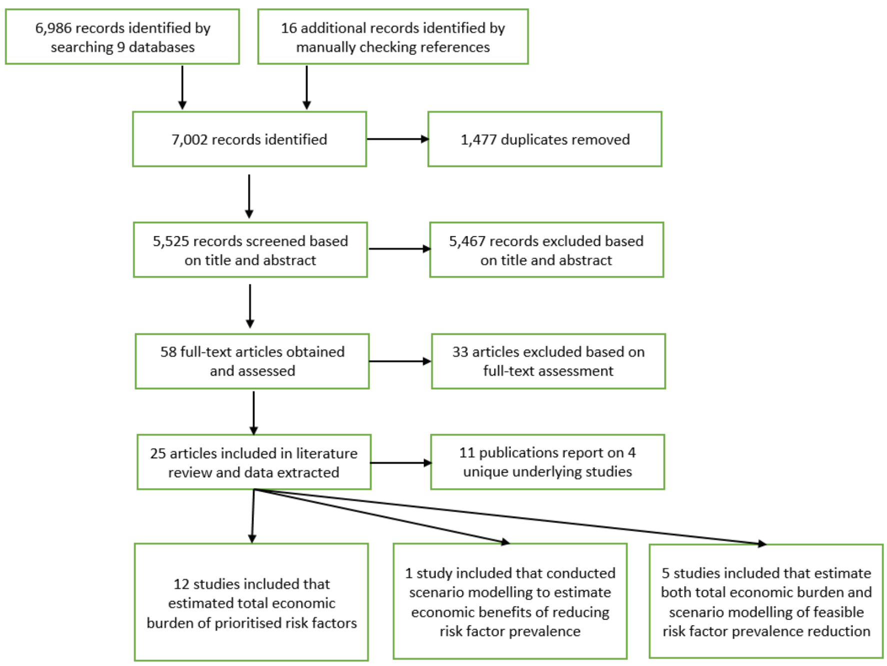

Table 1: Summary of selected methods adopted by included studies.

Study ID (references)	Risk factor	Population reference year	Population	Perspective	Proportion of costs attributed to risk factor	Health care costs	Non-health care costs to government	Productivity	Macroeconomic impacts[a]	Monetised value of health	Funding source
Access Economics 2008 (13)	Obesity	2008	All Australians	Societal,[b] cost results reported per payer	Population attributable fractions	Top-down, based on total cost of linked diseases; included: informal care, out of pocket costs	Bottom-up; included income tax, welfare payments, deadweight loss due to taxation[c]	Bottom-up, human capital approach, linked to disease; included: reduced employment (including early retirement), absenteeism, premature mortality (including recruitment costs of new staff)	Not included	Bottom-up, attributable DALYs multiplied by VSLY of $266,843	Diabetes Australia, sanofi-aventis
Beavis 2014 (14)	Physical inactivity	2008	Melbourne	Societal[b]	Not stated, adapted from model used by Cadilhac 2009	Not stated, adapted from model used by Cadilhac 2009	Not included	Not stated, adapted from model used by Cadilhac 2009	Not included	Health burden estimated but not monetised	None declared
Cadilhac 2009 (15-17, 27, 28)	Alcohol, fruit and vegetables, physical inactivity, tobacco, BMI, intimate partner violence	2008	All Australians	Societal[b]	Population attributable fractions	Top-down, based on total cost of health expenditure	Bottom-up, income taxation effects	Bottom-up, human capital approach and friction cost approach, dependent on risk factors not disease; included: workforce productivity (premature mortality, participation, absenteeism), leisure-based production, home-based production	Not included	Health burden estimated but not monetised	VicHealth
Colagiuri 2010 (18)	Overweight & obesity	2005	All Australians	Societal	Directly obtained from individual data	Bottom-up, based on individual survey data (some medication excluded)	Bottom-up, based on individual survey data; included aged pension, disability pension, veteran pension, mobility allowance, sickness allowance, unemployment benefit	Not included	Not included	Not included	Diabetes Australia Research Trust, Sanofi-Aventis Australia
Collins 2008 (19, 20)	Alcohol, tobacco, illicit drugs	2005	All Australians	Societal	Population attributable fractions	Top-down, based on total expenditure; included hospitals, medical costs, pharmaceuticals, nursing homes and ambulance	Top-down, policing, criminal courts, prisons, customs	Demographic approach; included, associated with risk factors: workforce productivity (premature mortality, absenteeism), home-based production, consumption resources saved	Not included	Value of the loss of one year's living, $53,267 (2005)	Australian Government Department of Health and Ageing
Collins 2010 (21)	Tobacco	2007	NSW population	Societal	Population attributable fractions	Top-down, based on total expenditure	Top-down	Demographic approach	Not included	Value of the loss of one year's living, amount not specified	NSW Department of Health
DAE 2016 (22)	Inadequate fruit and vegetable consumption	2016	All Australians	Government health expenditure and vegetable producers	Population attributable fractions	Top-down, based on total expenditure	Not included	Potential increased profits to producers of vegetables, top down based on expected changes to volumes produced	Not included	Not included	Horticulture Innovation Australia
Ding 2016 (9)	Physical inactivity	2013	Global population	Societal	Population attributable fractions	Average annual cost per case of disease	Not included	Friction cost approach for premature mortality	Not included	Health burden estimated but not monetised	None to declare
Doidge 2012 (23)	Insufficient dairy	2011	All Australians	Health care sector	Modified population attributable fraction method for continuous variable	Top-down, based on total expenditure	Not included	Not included	Not included	Health burden estimated but not monetised	Dairy Australia
Duckett 2016 (24)	Obesity	2015	All Australians	Third-party payer	Demographic, number of people with risk factor multiplied by additional costs	Bottom-up, based on additional cost due to risk factor from Colagiuri 2010 and PWC 2015	Foregone income tax and company tax, based on lower participation rates linked to risk factor; welfare; deadweight loss[c]	Not included	Not included	Not included	Various

Table 1 cont.: Summary of selected methods adopted by included studies.

Study ID (references)	Risk factor	Population reference year	Population	Perspective	Proportion of costs attributed to risk factor	Health care costs	Non-health care costs to government	Productivity	Macroeconomic impacts[a]	Monetised value of health	Funding source
KPMG 2010 (25, 31)	Obesity	2009	All Australians	Societal	Population attributable fractions	Top-down, based on total expenditure per disease		Human capital approach (not stated); included: premature mortality, workforce productivity (absenteeism (linked to risk factor), presenteeism (linked to disease))	Using a macro-industry econometric model (CGE); included: GDP, private consumption, investment, exports, imports	Top-down, attributable DALYs per disease multiplied by VSLY of $266,843 (2009)	Medibank
Laslett 2010 (26)	Alcohol	2005	People impacted by another's drinking	Societal	Population attributable fractions	Bottom-up, based on survey data	Not included	Time spent in hospital multiplied by average weekly earnings; lost production due to premature mortality not included	Not included	QALYs valued at $50,000	Alcohol Education and Rehabilitation Foundation
Manning 2013 (29)	Alcohol	2010	All Australians	Societal	From literature on a cost-by-cost basis	Bottom-up; included: hospital, nursing home, pharmaceutical, ambulance	Both top-down and bottom-up approaches; included: criminal justice system (police, courts, prisons, child protection and support services)	Approach not stated, presumably human capital approach; included: premature mortality, reduced workforce participation, absenteeism, home based production, production lost due to incarcerated individuals	Not included	Not included	Not stated
Medibank 2008 (30)	Physical inactivity	2008	All Australians	Societal	Method not reported	Methods not reported	Not included	Methods not reported; included premature mortality, absenteeism, presenteeism	Methods not reported, may be included in productivity estimate	Estimated but not monetised	Medibank
NSW AG 2013 (32)	Alcohol	2010	NSW population	NSW government agencies	Methods not reported	Methods not reported	Methods not reported	Methods not reported	Not included	Estimated but not monetised	NSW Audit Office
PWC 2015 (33, 34)	Obesity	2012	All adult Australians	Societal	Bottom-up, average excess cost or resource use of obese people	Bottom-up, based on cost per obese person; included GP, allied health, specialists, hospital, pharmaceuticals, weight loss interventions	Bottom-up; included disability payments, unemployment and public interventions, forgone income tax	included: absenteeism (linked to risk factor), presenteeism (linked to proportion of disease attributable to obesity), foregone earnings (based on reduced participation rate)	Not included	Attributable DALYs multiplied by VSLY of $183,203 (2015)	Obesity Australia
Roche 2016 (35)	Alcohol	2013	Working Australians	Australian employers	Not included	Not included	Not included	Bottom-up, based on survey data, linked to risk factor; included: absenteeism only	Not included	Not included	No conflicts to declare
Scalley 2013 (36)	Overweight & obesity	2011	Western Australians	Acute hospital system	Population attributable fractions	Bottom-up; included inpatient separations, emergency presentations	Not included	Not included	Not included	Not included	WA Department of Health

Notes:

Acronyms: NSW – New South Wales; DALY – disability-adjusted life years; VSLY – value of a statistical life year; WA – Western Australia; QALY – quality-adjusted life year; ACT – Australian Capital Territory; GP – General Practitioner

a: Macroeconomic impacts are indirect effects on the economy beyond that produced by the person themselves. This includes Gross Domestic Product, unemployment, inflation, imports, experts and foreign exchange rates

b: The perspective is not clearly stated in the study. An assessment of the likely perspective is reported based on the costs included in the studies

c: Deadweight loss refers to the loss of benefit to both the producer and consumer of a service as a result of distortions to the market for those services caused by taxes or some other impediment to the operation of a free and open market forgone. These estimates ranged from $866 million to $3.8 billion per year due to obesity, with more recent studies yielding higher amounts.[13,24,33,34] The annual value of production lost due to obesity was estimated in four studies with estimates ranging from $840 million to $14.9 billion per year.[13,24,25,31,33,34] The larger estimate includes macroeconomic impacts, such as Gross Domestic Product (GDP), private consumption, exports and imports, but these were not reported separately from other production impacts.[25,31] Three studies on obesity calculated a monetised value of health loss using a Value of a Statistical Life Year (VSLY; a process of applying a dollar value to years of life gained or lost) applied to attributable DALYs.[13,25,31,33,34] These estimates ranged from $34.5 billion to $59.4 billion per year. The health burden attributable to obesity was substantial with annual estimates ranging from 130,669 DALYs to 258,573 DALYs for the whole Australian population.[13,25,31,33,34]

The authors of two studies conducted a scenario analysis of reducing the prevalence of overweight and obesity[15,17,33,34] (Table 3).

Tobacco smoking

Authors of three studies explored the economic cost attributable to tobacco use in Australia with one of these focusing on the state of New South Wales (NSW; represents approximately 30% of the Australian population)[15,17,19,21,27] (Table 2). Estimates of ascribable healthcare costs for the 2008 Australian population were $415 million for one year[19] and $1.67 billion over their lifetime.[15,17,27] Over the lifetime of the 2008 Australian population, the estimated value of taxation forgone due to tobacco smoking was $1.06 billion using the human capital approach (estimates the cost of years of productive capacity lost due to premature death or retirement over the normal working lifetime of a person) and $182 million for the friction cost approach (assumes that a person no longer able to work due to premature death or retirement would normally be replaced and costs to the employer and forgone taxes only accrue for a short period while the replacement worker is recruited and trained [say 3 or 6 months]).[15,17,27] Estimates of production forgone due to tobacco for the Australian population ranged from $10.5 billion for one year[19] to $10.2 billion over the lifetime of the 2008 Australian population.[15,17,27]

Cadilhac et al. investigated the impact of reducing the prevalence of smoking for the whole Australian population[15,17,27] and Collins et al. invesigated the impact on the NSW population only[21] (Table 3).

Alcohol

The authors of six studies explored the economic impact of alcohol consumption[15,17,19,26,28,29,32,35] (Table 2). One of these studies contained a focus on the NSW population,[32] one on working Australians only[35] and one on people affected by the alcohol use of someone else,[26] with the rest of the studies including the whole Australian population.

Estimates of healthcare costs attributable to alcohol for Australia ranged from $1.89 billion[29] to $2.58 billion[19] for one year and $2.69 billion over the lifetime of the 2008 population.[15,17,28] Studies that reported these costs by healthcare setting found costs were generally evenly spread over primary care, secondary care and nursing homes. The studies included a diverse range of non-healthcare costs to government, such as taxation effects, road accidents, police, criminal courts, prisons, child protection services and out-of-home community services. The annual cost of traffic accidents and the criminal justice system were the largest in this category, with Collins and Lapsley estimating costs of $2.89 billion due to traffic accidents and $1.24 billion of criminal justice system costs attributable to alcohol.[19] Manning et al. estimated that in one year $3.35 billion of criminal justice system costs and $4.14 billion of traffic accidents costs were attributable to alcohol.[29] These non-healthcare costs to government substantially outweighed health service costs. This was somewhat unique to alcohol consumption compared with other risk factors.

The authors that studied alcohol all estimated impact on productivity. One study found substantial positive effects on workforce production associated with alcohol consumption when adopting the human capital approach.[15,17,28] This counterintuitive positive impact of $5.34 billion over the lifetime of the 2008 Australian population, in turn reflects data in the National Health Survey 2004–05, used to inform this model. The result infers that workforce participation in young males and most female high-risk alcohol consumers was higher than persons reporting low-risk alcohol consumption. Although these differences may not have reached statistical significance, the approach was consistently applied to all risk factors in that study. Under the human capital approach, this accumulates and results in the high positive workforce production impact associated with alcohol consumption. In contrast, the alternative friction cost approach used in the same study found a negative impact of alcohol consumption on workforce productivity, as intuitively expected. Because the friction cost approach captures only a portion of a year's income, it does not weight the behaviour of the younger age groups as heavily as the human capital approach. In a separate study, Collins and Lapsley found a more intuitive negative impact on workforce production of $3.58 billion and home-based production impacts of $1.57 billion,[19] both over one year. This analysis appears to have used different data linking alcohol consumption with workforce participation, although this is not clearly reported. The other studies supported the intuitive finding on negative effects of alcohol consumption on workforce production, with annual estimates ranging from $1.12 billion to $6.84 billion.[29,32,35]

The authors of two studies conducted a scenario analysis of the economic impact of reductions in alcohol consumption[15,17,20,28] (Table 3).

Physical inactivity

Three studies contained an investigation of the economic impact of physical inactivity[9,14-17,30] (Table 2). Estimates of attributable annual healthcare costs ranged from $681.1 million to $850 million for the Australian population. The diseases that contributed most to healthcare costs were generally cardiovascular disease, type 2 diabetes and falls. Cadilhac et al. included workforce, home-based and leisure-based production impacts in their analysis of the Australian population. They estimated the total production impacts due to physical inactivity to be $2.41 billion based on the human capital approach and $1.35 billion based on the friction cost approach[15-17] over the lifetime of the 2008 Australian population. Ding et al. estimated workforce production losses due to premature mortality based on the friction cost approach and calculated that $176 million was attributable to physical inactivity[9] for one year. Medibank estimated that the value of lost production due to premature mortality due to physical inactivity

Table 2: Economic impact of preventable disease, summary of headline results.

Study ID (references)	Risk factor	Population	Population reference year	Timeframe	Health care costs ($M)	Non-health care cost to government ($M)	Productivity loss ($M)	Monetised health loss ($M)	Health loss
Multiple risk factors									
Cadilhac 2009 (15, 17)	Alcohol, fruit and vegetables, physical inactivity, tobacco, BMI >25, intimate partner violence	All Australians	2008	Lifetime of 2008 cohort	6,299.1	90.5	8,099.4	Estimated but not monetised	26,000 deaths; 414,000 DALYs
Collins 2008a (19)	Alcohol, tobacco, illicit drugs	All Australians	2005	One year	3,187.9	4,830.9	16,937.4	31,830.9	16208 deaths
Overweight & obesity									
Access 2008 (13)	Obesity	All Australians	2008	One year	4,643.0	866.0	4,323.1	59,439.3	197,729 DALYs
Cadilhac 2009 (15, 17)	Overweight & obesity	All Australians	2008	Lifetime of 2008 cohort	959.8	52.4	1,044.7	Estimated but not monetised	198,000 DALYs; 10,000 deaths
Colagiuri 2010 (18)	Overweight & obesity	All Australians	2005	One year	13,690.5	Not included	Not included	Not included	Not included
Duckett 2016 (24)	Obesity	All Australians	2015	One year	2,672.5	2,725.2	839.6	Not included	Not included
KPMG 2010 (25, 31)	Obesity	All Australians	2009	One year	1,513.8	Not included	14,852.8	34,545.6	130,669 DALYs
PWC 2015 (33, 34)	Obesity	All adult Australians	2012	One year	3,910.7	3,870.7	13,160.1	48,653.7	258,573 DALYs
Scalley 2013 (36)	Overweight & obesity	Western Australians	2011	One year	267.8	Not included	Not included	Not included	Not included
Tobacco									
Cadilhac 2009 (15, 17, 27)	Tobacco	All Australians	2008	Lifetime of 2008 cohort	1,669.0	1,061.4	10,281.8	Estimated but not monetised	205,000 DALYs; 16,000 deaths
Collins 2008a (19)	Tobacco	All Australians	2005	One year	415.1	0.0	10,508.7	25,532.9	14,901 deaths
Collins 2010 (21)	Tobacco	NSW population	2007	One year	140.2	757.0	3,447.3	6,716.0	4,810 deaths
Alcohol									
Cadilhac 2009 (15, 17, 28)	Long term high risk alcohol consumption	All Australians	2008	Lifetime of 2008 cohort	2,689.1	-1,464.1	-5,339.2	Estimated but not monetised	61,000 DALYs; 1,000 deaths
Collins 2008a (19)	Alcohol	All Australians	2005	One year	2,577.3	1,868.4	4,642.2	5,889.6	1,057 deaths
Laslett 2010 (26)	Alcohol	Australians impacted by the alcohol use of another	2005	One year	*	*	*	*	*
Manning 2013 (29)	Alcohol	All Australians	2010	One year	1,890.1	7,488.3	6,839.0	Not included	Not included
NSW AG 2013 (32)	Alcohol	NSW population	2010	One year	645.4	1,332.9	2,100.3	Estimated but not monetised	1,210 deaths
Roche 2016 (35)	Alcohol	Working Australians	2013	One year	Not included	Not included	1,118.7	Not included	Not included
Physical inactivity									
Cadilhac 2009 (15-17)	Physical inactivity	All Australians	2008	Lifetime of 2008 cohort	794.3	103.6	2,408.7	Estimated but not monetised	174,000 DALYs; 13,000 deaths
Ding 2016 (9)	Physical inactivity	All Australians	2013	One year	681.1	Not included	175.9	Estimated but not monetised	38,900 DALYs
Medibank 2008 (30)	Physical inactivity	All Australians	2008	One year	849.9	Not reported separately	15,619.8	Estimated but not monetised	174,431 DALYs; 16,178 deaths
Diet									
Cadilhac 2009 (15, 17)	Consumption below the recommended minimum of 2 serves of fruit and 5 serves of vegetables	All Australians	2008	Lifetime of 2008 cohort	243.5	38.1	561.1	Estimated but not monetised	55,000 DALYs; 5,000 deaths
Doidge 2012 (23)	Insufficient dairy	All Australians	2011	One year	2,230.0	Not included	Not included	Estimated but not monetised	75,012 DALYs
DAE 2016 (22)	Inadequate vegetable consumption	All Australians	2016	One year	990.4	Not included	Not included	Estimated but not monetised	62,751 DALYs

Notes:
Acronyms: DALY – disability-adjusted life year; NSW – New South Wales; BMI – body mass index
Indexation: Values in the column labelled 'Health care costs' have been inflated to the 2016-17 financial year using the Australian Institute of Health and Welfare's total health price index. Dollar values in the columns labelled 'Non-health care costs to government', 'Productivity' and 'Health loss' columns have been inflated to the 2016-17 financial year using the GDP Implicit Price Deflator.
**Laslett 2010 is an exploration of a variety of methods and sources of data with different results provided for each approach, making extraction of a single representative set of results impossible. In the authors' own words, "The report does not end up with a single figure, for instance of the total burden of disease and distress from others' drinking or of the total cost to others. In our view, such an effort would be premature, and in itself not very revealing."*
Cadilhac 2009 (and its associated papers) calculated productivity impacts using both the friction cost and human capital approach. Only results based on the human capital approach have been reported here for the sake of tractability.
Cadilhac 2009 (and its associated papers) include intimate partner violence in its estimates of the joint effects of multiple risk factors. Although intimate partner violence was not prioritised as a risk factor of interest for the present review, the total estimates of joint effects including intimate partner violence have been reported here for the sake of tractability. The other five risk factors included in these joint effect estimates are the five risk factor prioritised for the present review.

Table 3: Potential economic gain from reducing risk factor prevalence, summary of scenarios.

Study ID (references)	Scenarios modelled	Source of risk factor reduction targets	Population	Population reference year	Timeframe	Range of health care cost savings		Range of non-health care cost savings to government		Range of productivity gains		Range of total potential monetary benefits		Range of potential health benefits
						Lower limit ($M)	Upper limit ($M)	Lower limit ($M)	Upper limit ($M)	Lower limit ($M)	Upper limit ($M)	Lower limit ($M)	Upper limit ($M)	
Multiple risk factors														
Cadilhac 2009* (15, 17)	3% and 1.5% reduction in prevalence of high BMI; 8% and 4% reduction in prevalence of tobacco smoking; reduction of 3.4 and 1.7 litres of alcohol per capita per year; 10% and 5% decrease in Australian adults with either sedentary or low activity level from 70%; increase of 172 and 86 grams per day per person of fruit and vegetable consumption; 2.5% and 5% reduction in prevalence of IPV	Alcohol, tobacco and IPV: prevalence levels observed in comparable countries; inadequate fruit and vegetables, high BMI and physical inactivity: literature review and expert advice from an advisory committee	All Australians	2008	Lifetime of 2008 cohort	888.9	1,777.8	-26.0	-13.0	918.4	1,835.7	1,807.3	3,613.5	48,000 to 95,000 DALYs; 3,000 to 6,000 deaths
Overweight and obesity														
Cadilhac 2009* (15, 17)	3% and 1.5% reduction in prevalence of high BMI	literature review and expert advice from an advisory committee	All Australians	2008	Lifetime of 2008 cohort	53.2	106.4	2.4	5.9	102.8	205.7	156.0	312.1	13,000 to 25,000 DALYs; 1,000 to 1,000 deaths
PwC 2015 (33, 34)	3.4% reduction in the prevalence of obesity between 2016 and 2025 (based on ACE/McKinsey set of interventions); 21.6% reduction in prevalence of obesity between 2016 and 2025 (WHO target)	Overall reduction in obesity based on a set of interventions assessed in previous work by ACE-Prevention and McKinsey Global Institute; WHO target of 2010 obesity prevalence levels	All Australians	2012	10 years	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	2,135.5	10,605.7	176,900 to 249,600 less obese people by 2025
Tobacco														
Cadilhac 2009* (15, 17, 27)	8% and 4% reduction in prevalence of tobacco smoking	prevalence levels observed in comparable countries	All Australians	2008	Lifetime of 2008 cohort	290.8	580.4	177.3	353.4	1,747.0	3,477.5	2,037.8	4,057.9	36,000 to 71,000 DALYs; 3,000 to 5,000 deaths
Collins 2010 (21)	Smoking prevalence reduction from 18.6% in 2007 to 12.6% in 2016; various scenarios of lag between reduction in prevalence and reduction in social costs, period of analysis, and discount rates	Target reduction in smoking rates presented in the NSW State Plan	NSW population	2007	20 years	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	2,909.2	22,770.0	Not reported
Alcohol														
Cadilhac 2009* (15, 17, 28)	Reduction of 3.4 and 1.7 litres of alcohol per capita per year	prevalence levels observed in comparable countries	All Australians	2008	Lifetime of 2008 cohort	466.9	932.6	-500.0	-250.6	-1,810.9	-912.5	-445.6	-878.3	11,000 to 21,000 DALYs; 190 to 380 deaths
Collins 2008b (20)	Reductions in per capita alcohol consumption of 38.8%, 14.3%, 18.4%, 16%, 11%, 21%, 6%, 25.2%, 16.3%, 33.6%;	Literature review and alcohol consumption levels achieved in comparable countries	All Australians	2005	One year	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	Disaggregated results not reported	365.1	5,032.9	1,668 deaths

Table 3 cont.: Potential economic gain from reducing risk factor prevalence, summary of scenarios.

Study ID (references)	Scenarios modelled	Source of risk factor reduction targets	Population	Population reference year	Timeframe	Range of health care cost savings		Range of non-health care cost savings to government		Range of productivity gains		Range of total potential monetary benefits		Range of potential health benefits
						Lower limit ($M)	Upper limit ($M)	Lower limit ($M)	Upper limit ($M)	Lower limit ($M)	Upper limit ($M)	Lower limit ($M)	Upper limit ($M)	
Physical inactivity														
Beavis 2014 (14)	10% of vehicle users change to either public transport or cycling	Arbitrary	Melbourne population	2008	Lifetime of 2008 cohort	4.8	6.8	Not included	Not included	8.9	12.6	13.6	20.4	1,148 to 1,635 DALYs; 89 to 127 deaths
Cadilhac 2009* (15-17)	10% and 5% decrease in Australian adults with either sedentary or low activity level from 70%	literature review and expert advice from an advisory committee	All Australians	2008	Lifetime of 2008 cohort	56.7	113.5	7.1	14.2	171.4	340.4	228.1	453.9	12,000 to 25,000 DALYs; 1,000 to 2,000 deaths
Diet														
Cadilhac 2009* (15, 17)	increase of 172 and 86 grams per day per person of fruit and vegetable consumption	literature review and expert advice from an advisory committee	All Australians	2008	Lifetime of 2008 cohort	41.4	83.9	5.9	13.0	95.7	190.3	137.1	274.2	9,000 to 19,000 DALYs; 1,000 to 2,000 deaths
DAE 2016 (22)	Consumption of vegetables 10% higher across the entire population; consumption by males equal to females	Literature review, ABDS 2011	All Australians	2016	One year	58.7	100.2	Not included	Not included	11.1	23.3	Not reported	Not reported	No reported

Notes:

Acronyms: ACT – Australian Capital Territory; NSW: New South Wales; DALY – disability-adjusted life years; WHO – World Health Organisation; ACE – Assessing Cost-Effectiveness study; ABDS – Australian Burden of Disease Study; BMI – body mass index; IPV – intimate partner violence.

Indexation: Values in the Health care cost savings column have been inflated to the 2016-17 financial year using the Australian Institute of Health and Welfare's total health price index. Dollar values in the other three columns have been inflated to the 2016-17 financial year using the GDP Implicit Price Deflator.

** Cadilhac 2009 (and its associated papers) calculated productivity impacts using both the friction cost and human capital approach. Only results based on the human capital approach have been reported here for the sake of tractability.*

** Cadilhac 2009 (and its associated papers) include intimate partner violence in its estimates of the joint effects of multiple risk factors. Although intimate partner violence was not prioritised as a risk factor of interest for the present review, the total estimates of joint effects including intimate partner violence have been reported here for the sake of tractability. The other five risk factors included in these joint effect estimates are the five risk factor prioritised for the present review.*

'Not reported separately' means estimates for this cost category were calculated but disaggregated results were not reported and have been included in other values provided in that row of the table.

'Not included' means the impacts on that cost category was not conducted in that study.

was $4.54 billion for one year based on the human capital approach.[30] The authors of this study found that the additional impact of presenteeism and absenteeism on Gross Domestic Product was $11.08 billion for one year, with the latter calculated by a computable general equilibrium model (methods not reported by the authors). For the Australian population, Ding et al. estimated that physical inactivity contributed 38,900 DALYs per year; Medibank estimated it contributed 174,431 DALYs per year and 16,178 deaths per year; and Cadilhac et al. estimated it contributed to 174,000 DALYs and 13,000 deaths[9,15-17,30] over the lifetime of the 2008 population. None of the studies on physical inactivity contained monetisation of the health loss associated with this risk factor.

Two studies contained a scenario analysis estimating the impact of improvements in physical activity[14-17] (Table 3).

Diet

The authors of three studies estimated the economic loss associated with various components of poor diet: inadequate fruit and vegetable consumption;[15,17] insufficient dairy consumption;[23] and inadequate vegetable consumption[22] (Table 2). Deloitte Access Economics estimated that inadequate vegetable consumption contributed to $990 million of healthcare costs and 62,751 DALYs in one year.[22] Doidge et al. estimated that insufficient dairy consumption contributed to $2.23 billion of healthcare costs and 75,012 DALYs in one year.[23] Cadilhac et al. estimated that insufficient fruit and vegetable consumption contributed to $243.5 million of healthcare costs, $561.1 million of production losses based on the human capital approach, $75 million of production losses based on the friction cost approach, 55,000 DALYs and 5,000 deaths over the lifetime of the 2008 Australian population.[15,17] Health impacts related to a poor diet were not monetised by any study.

Two studies contained scenario modelling estimating the economic impacts of improvements to diet.[15,17,22]

Discussion

Authors of the studies included in this review found that chronic disease and other harms associated with overweight and obesity, smoking, alcohol use, unhealthy diet and physical inactivity caused substantial economic cost to Australians, the healthcare system, governments, business and the broader economy. Estimates vary widely depending on the risk factors included, costs included, timeframe and other methodological approaches. In terms of healthcare expenditure, multiple studies demonstrated that a substantial portion of total healthcare expenditure was attributable to obesity, with estimates ranging from $1.5 billion to $4.6 billion per year. When overweight was included for all Australians, the estimate of ascribable healthcare expenditure was $13.7 billion for a single year. Attributable health expenditure was also sizeable for the Australian population for the other prioritised risk factors: up to $2.57 billion for alcohol consumption, up to $850 million for physical inactivity, up to $990 million for inadequate vegetable consumption and $2.2 billion for insufficient dairy consumption. The study on dairy consumption is unlikely to represent current evidence on the importance of this dietary component, with recent studies showing nutritional requirements can be met with a plant-based diet.[39] Medibank and Cadilhac et al. reported quite similar estimates of health burden attributable to physical inactivity of 174,431 DALYs and 174,000 DALYs, respectively.

Estimates of non-healthcare costs to government attributable to the risk factors varied widely, potentially due to the degree of analyst discretion about what to include and exclude in this category. Regardless, they were large, with attributable estimates up to $3.87 billion and $7.49 billion annually for the Australian population for obesity and alcohol respectively. Production losses were often much larger than healthcare and other costs to government. For example, annual production losses for the Australian population due to obesity were up to $14.85 billion, up to $6.84 billion for alcohol and up to $15.6 billion due to physical inactivity. One of the elements that substantially influenced estimates of reductions in productivity was the inclusion of flow-on macroeconomic impacts. This was conducted in only two of the included studies based on a computable general equilibrium (CGE) model developed by KPMG, published in 2008 and 2010.[25,30,31] CGE models are very resource intensive to develop and attempt to capture the complex interactions between the various sectors of an economy based on neoclassical economic theory.

Studies found that substantial economic costs can be averted with reasonable reductions in the prevalence of these risk factors.

Much of the variability in study results can be explained by the methodological approaches adopted in the analysis and input data used to populate the model. For example, the prevalence of risk factors varied depending on the source of data and when the analysis was done. Table 4 (Supplementary File) summarises the prevalence proportions used in included studies and definitions they were based on. In the 2008 report by Access Economics a prevalence of obesity of 17.5% was used but the latest estimates of the National Health Survey found that the prevalence of obesity in adults was 31.3% in 2017–18.[40] Similarly, the prevalence of smoking used by Cadilhac et al. in 2009 was 23%, but only 13.8% of adults reported they were daily smokers in 2017–18, although this figure excludes chewing tobacco, electronic cigarettes and smoking of non-tobacco products.[40] This will affect both the estimates of total economic burden attributable to that risk factor and also the targets adopted in scenario analysis in terms of further improvements that can reasonably be achieved. It highlights the limitations of adopting a static prevalence measure. Future research using simulation modelling that includes historical and likely trends of risk factor prevalence provides an opportunity to better capture population trends over time and more accurately calculate the dynamic nature of the attributable burden. The choice of most appropriate economic value to represent health loss had a large impact on estimates of the economic burden. Authors that used the VSLY to value the DALY reported much higher economic burden estimates compared to studies that did not attempt to value health loss in monetary terms. Studies of multiple risk factors tended to be funded by government-related entities, whereas studies focusing on a single risk factor tended to be funded by a commercial entity or advocacy organisation.

The actions related to managing non-communicable disease are often under the remit of government health departments; however, the economic cost of poor health has larger impacts on the business sector (through impacts on productivity) and the individual (through lost income, reduced home-based production and health impacts) compared to the healthcare sector. Given that lifestyle-related risk factors are largely a product of our environment,[41,42] effective solutions will require action across several government departments (not just the health department) and will need to be complemented by actions by the private sector and civil society.[43] Therefore, building the evidence of the economic impact of non-communicable disease across all members of society may be important to highlight the need for a societal response to preventable disease. For example, non-communicable disease is only one of the harms caused by alcohol consumption. Other consequences included interpersonal violence, injuries to self, road vehicle accidents, costs incurred by the criminal justice system, and harms caused to people other than the drinker, as studied by Laslett et al. (one of the included studies in this review).[26]

A large portion of evidence for this review was from the grey literature rather than peer-reviewed publications, highlighting the importance of considering this type of reporting when looking for economic analyses. The majority of studies adopted a societal perspective, which is appropriate in the current context of attempting to account for the various consequences of modifiable risk factors and maximise societal welfare. The majority of studies adopted the human capital approach to estimating production impacts. The most appropriate method of accounting for productivity impacts is still open to debate, but most researchers adopt the human capital approach, and this aligns with the Second US Panel on Cost-effectiveness in Health and Medicine's recommendation.[44]

Existing studies provide a compelling case to prioritise action on reducing the prevalence of lifestyle-related risk factors; however, there are several gaps in the current evidence base. Several risk factors share joint causal responsibility for many non-communicable diseases.[7,42] Evidence on the joint effects of multiple risk factors provides some of the evidence required to justify a national strategy to focus on the prevention of non-communicable diseases; however, the last time the joint economic impact of lifestyle-related risk factors for the whole Australian population was studied was 10 years ago.[15-17,27,28] A new analysis with updated data on risk factor prevalence, linked diseases, strength of associations, and costs would be useful. Dietary risk factors appear to be an understudied area relative to the degree of health burden they are responsible for. The Global Burden of Disease Study 2016 included 15 individual component dietary risks in its assessment of preventable disease, including diets high in red meat, low in whole grains, low in nuts and seeds, high in processed meat, high in sugar-sweetened beverages and high in sodium. However, the studies included in this review focused only on diets low in fruit, vegetables and dairy. Considering that dietary risk factors account for 27,500 deaths per year, which is more than smoking, and 7.9% of overall fatal and non-fatal health burden (measured in DALYs),[1] further research on the economic impact in this area would help to motivate and inform government and societal action.

Source data informing participation rates and absenteeism was linked to either risk factors or disease. Linking to risk factors rather than disease sometimes produced counterintuitive results, such as positive production impacts due to alcohol consumption and lower absenteeism rates being associated with lower fruit and vegetable consumption. This highlights the limitations of relying on cross-sectional surveys to establish these associations because the disease caused by these risk factors may only occur years after exposure to the risk factor. Presenteeism was included in only three studies.[25,30,31,33,34] Further investigation is warranted into the most appropriate method of linking absenteeism, workforce participation and presenteeism to risk factors and if more appropriate data from longitudinal data sets are available. Another parameter that contributes substantially to the overall economic impact is the dollar value assigned to the health measure to monetise the impact on population health. The most common method was using a VSLY, but these values vary widely (range $183,203 to $266,843). A systematic review of estimates would be a useful addition to future analyses in this area.

Another limitation of existing evidence is the reliance on cohort modelling to establish the economic cost related to a static population in a particular year or over their lifetime. A related limitation of the current evidence is the 'one-off' analysis and report style of providing information to decision-makers. An alternative that would enhance the usefulness of this analysis is having decision-makers involved in a collaborative model building process to develop dynamic simulation modelling of the risk factor burden, incorporating population dynamics, trends in risk factor prevalence and diseases over time, and making these models usable by decision-makers so they are able to conduct the scenario analyses that are relevant to their policy context and, ideally, be able to provide updated estimates as new data and evidence comes to light.[15,45]

Finally, it should be noted that a single author screened titles and abstracts, potentially reducing the accuracy of the screening process. The majority of economic evidence of this nature exists as grey literature that may not be indexed in the databases searched. This risk was mitigated by including databases that index grey literature relevant to health policy in Australia, such as Informit, Global Health and Google. The need to select risk factors for inclusion in the study to keep the analysis tractable means we have excluded economic analyses that investigate other modifiable risk factors that account for a large portion of the burden of disease in Australia – such as high blood pressure and high cholesterol. We believe the selected risk factors represent a substantial portion of preventable health burden and a substantial portion of studies that have been conducted on preventable disease in Australia.

While not part of this review, there is a strong and growing evidence base to support specific interventions to realise the potential for disease reduction.[46-49]

Conclusion

Chronic disease associated with overweight and obesity, smoking, alcohol use, unhealthy diet, and physical inactivity causes substantial economic cost to Australians, the healthcare system, governments, business and the broader economy. Sufficient, compelling economic evidence exists to support enhanced action to reduce the prevalence of these risk factors in Australia. The information reviewed in this article provides part of that economic evidence. In addition to evidence on the size, preventability and impact of risk factor reductions, policy action should also draw on the cost-effectiveness credentials of specific options for change.

It has been ten years since the last analysis estimating the economic burden of multiple risk factors concurrently was conducted. New analysis on this would be a useful addition to the evidence base, particularly in the area of the burden attributable to diet-related risk, using dynamic simulation modelling to more accurately represent the Australian population, risk factor prevalence and disease pathways over time.

Acknowledgements

This research was supported by The Australian Prevention Partnership Centre through the NHMRC partnership centre grant scheme (Grant ID: GNT9100001) with the Australian Government Department of Health, NSW Ministry of Health, ACT Health, HCF, and the HCF Research Foundation.

Role of the Funding Source

JD and ML are employees of the Sax Institute, which administers The Australian Prevention Partnership Centre. PC and JA are employees of Deakin University in positions that are fully or partly funded by The Australian Prevention Partnership Centre. The design of this study was influenced by the strategic objectives of The Australian Prevention Partnership Centre, publicly available from https://preventioncentre.org.au/. RC is an employee of Deakin University.

References

1. Gakidou E, Afshin A, Abajobir AA, Abate KH, Abbafati C, Abbas KM, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2016: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet*. 2017;390(10100):1345-422.
2. Australian Institute of Health and Welfare. *Australia's Health 2018*. Canberra (AUST): AIHW; 2018.
3. Crosland P, Ananthapavan J, Davison J, Lambert M, Carter R. The health burden of preventable disease in Australia: A systematic review. *Aust N Z J Public Health*. 2019. https://doi.org/10.1111/1753-6405.12882
4. Drummond M, Sculpher M, Torrance G, O'Brien B, Stoddart G. *Methods for the Economic Evaluation of Health Care Programmes*. 4th ed. Oxford (UK): Oxford University Press; 2015.
5. Access Economics. *The Economic Costs of Obesity*. Melbourne (AUST): Access Economics; 2006.
6. Signy H, Burgess A, Overs M. *Outcomes Report 2013 - 2018: Changing the System*. Sydney (AUST): The Australian Prevention Partnership Centre; 2018.
7. Stanaway JD, Afshin A, Gakidou E, Lim SS, Abate D, Abate KH, et al. Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1923-94.
8. Centre for Reviews and Dissemination. *Search Strategies* [Internet]. York (UK): University of York; 2018 [2018 Dec 18]. Available from: https://www.crd.york.ac.uk/CRDWeb/searchstrategies.asp
9. Ding D, Lawson KD, Kolbe-Alexander TL, Finkelstein EA, Katzmarzyk PT, van Mechelen W, et al. The economic burden of physical inactivity: A global analysis of major non-communicable diseases. *Lancet*. 2016;388(10051):1311-24.
10. World Bank. *What is an "International Dollar"?* [Internet]. Washington (DC): The Bank; 2018 [2018 Dec 18]. Available from: https://datahelpdesk.worldbank.org/knowledgebase/articles/114944-what-is-an-international-dollar
11. Australian Institute of Health and Welfare. *Health Expenditure Australia 2016-17*. Canberra (AUST): AIHW; 2018.
12. Australian Bureau of Statistics. *5206.0 - Australian National Accounts: National Income, Expenditure and Product*. Canberra (AUST): AIHW; 2018.
13. Access Economics. *The Growing Cost of Obesity in 2008: Three Years On*. Melbourne (AUST): Access Economics; 2008
14. Beavis MJ, Moodie M. Incidental physical activity in Melbourne, Australia: Health and economic impacts of mode of transport and suburban location. *Health Promot J Austr*. 2014;25(3):174-81.
15. Cadilhac D, Magnus A, Cumming T, Sheppard L, Pearce D, Carter R. *The Health and Economic Benefits of Reducing Disease Risk Factors*. Melbourne (AUST): Deakin University; 2009.
16. Cadilhac DA, Cumming TB, Sheppard L, Pearce DC, Carter R, Magnus A. The economic benefits of reducing physical inactivity: An Australian example. *Int J Behav Nutr Phys Act*. 2011;8:99.
17. Cadilhac DA, Magnus A, Sheppard L, Cumming TB, Pearce DC, Carter R. The societal benefits of reducing six behavioural risk factors: An economic modelling study from Australia. *BMC Public Health*. 2011;11:483-.
18. Colagiuri S, Lee CMY, Colagiuri R, Magliano D, Shaw JE, Zimmet PZ, et al. The cost of overweight and obesity in Australia. *Med J Aust*. 2010;192(5):260-4.
19. Collins DJ, Lapsley HM. *The Costs of Tobacco, Alcohol and Illicit Drug Abuse to Australian Society in 2004/05*. Canberra (AUST): Australian Department of Health and Ageing; 2008.
20. Collins DJ, Lapsley HM. *The Avoidable Costs of Alcohol Abuse in Australia and the Potential Benefits of Effective Policies to Reduce the Social Costs of Alcohol*. Canberra (AUST): Australian Department of Health and Ageing; 2008.
21. Collins DJ, Lapsley HM. *The Social Costs of Smoking in NSW in 2006/07 and the Social Benefits of Public Policy Measures to Reduce Smoking Prevalence*. Sydney (AUST): New South Wales Department of Health; 2010.
22. Deloitte Access Economics. *Impact Increasing Vegetable Consumption Health Expenditure*. Melbourne (AUST): Deloitte; 2016.
23. Doidge JC, Segal L, Gospodarevskaya E. Attributable risk analysis reveals potential healthcare savings from increased consumption of dairy products. *J Nutr*. 2012;142(9):1772-80.
24. Duckett S, Swerissen H. *A Sugary Drinks Tax, Recovering the Community Costs of Obesity*. Melbourne (AUST): Grattan Institute; 2016.
25. KPMG. *Economic Modelling of the Impact of Obesity and Obesity Interventions*. Melbourne (AUST): Medibank Private; 2010.
26. Laslett A-M, Catalano P, Chikritzhs T, Dale C, Doran C, Ferris J, et al. *The Range and Magnitude of Alcohols Harm to Others*. Canberra (AUST): Foundation for Alcohol Research and Education; 2010.
27. Magnus A, Cadilhac D, Sheppard L, Cumming T, Pearce D, Carter R. Economic benefits of achieving realistic smoking cessation targets in Australia. *Am J Public Health*. 2011;101(2):321-7.
28. Magnus A, Cadilhac D, Sheppard L, Cumming T, Pearce D, Carter R. The economic gains of achieving reduced alcohol consumption targets for Australia. *Am J Public Health*. 2012;102(7):1313-19.
29. Manning M, Smith C, Mazerolle P. *The Societal Costs of Alcohol Misuse in Australia*. Canberra (AUST): Australian Institute of Criminology; 2013.
30. Medibank. *The Cost of Physical Inactivity*. Melbourne (AUST): Medibank Private; 2008.
31. Medibank Health Solutions. *Obesity in Australia: Financial Impacts and Cost Benefits of Intervention*. Melbourne (AUST): Medibank Private; 2010.
32. New South Wales Auditor-General. *Cost of Alcohol Abuse to the NSW Government*. Sydney (AUST): State Government of NSW; 2013.
33. Obesity Australia. *Obesity Impact on Australia and Case for Action*. Melbourne (AUST): OA; 2010.
34. PricewaterhouseCoopers. *Weighing the Cost of Obesity: A Case for Action*. Melbourne (AUST): PWC; 2015.
35. Roche A, Pidd K, Kostadinov V. Alcohol- and drug-related absenteeism: A costly problem. *Aust N Z J Public Health*. 2016;40(3):236-8.
36. Scalley B, Xiao J, Somerford P. *The Cost of Excess Body Mass to the Acute Hospital System in Western Australia*. Perth (AUST): Western Australia Department of Health; 2013.
37. Kyu HH, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017. *Lancet*. 2018;392(10159):1859-922.
38. Salomon JA, Haagsma JA, Davis A, de Noordhout CM, Polinder S, Havelaar AH, et al. Disability weights for the Global Burden of Disease 2013 study. *Lancet Glob Health*. 2015;3(11):e712-e23.
39. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: The EAT–Lancet Commission on healthy diets from sustainable food systems. *Lancet*. 2019;393(10170):447-92.
40. Australian Bureau of Statistics. *National Health Survey First Results Australia 2017-18*. Canberra (AUST): ABS; 2018.
41. Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, et al. The global obesity pandemic: Shaped by global drivers and local environments. *Lancet*. 2011;378(9793):804-14.
42. Swinburn BA, Kraak VI, Allender S, Atkins VJ, Baker PI, Bogard JR, et al. The Global Syndemic of Obesity, Undernutrition, and Climate Change: The Lancet Commission Report. *Lancet Commissions*. 2019;393(10173):791-846.
43. Gortmaker SL, Swinburn BA, Levy D, Carter R, Mabry PL, Finegood DT, et al. Changing the future of obesity: Science, policy, and action. *Lancet*. 2011;378(9793):838-47.
44. Neumann PJ, Sanders GD, Russell LB, Siegel JE, Ganiats TG. *Cost-effectiveness in Health and Medicine*. 2nd ed. New York (NY): Oxford University Press; 2017.
45. Freebairn L, Atkinson JA, Kelly PM, McDonnell G, Rychetnik L. Decision makers' experience of participatory dynamic simulation modelling: Methods for public health policy. *BMC Med Inform Decis Mak*. 2018;18(1):131.
46. World Health Organization. *Tackling NCDs, 'Best Buys' and Other Recommended Interventions for the Prevention and Control of Noncommunicable Diseases*. Geneva (CHE): WHO; 2017.
47. Vos T, Carter R, Barendregt J. *Asessing Cost-effectiveness in Prevention (ACE-Prevention): Final Report*. Brisbane (AUST): University of Queensland; 2010.
48. Sacks G, Robinson E. *Policies for Tackling Obesity and Creating Healthier Food Environments: Scorecard and Priority Recommendations for Australian Governments*. Melbourne (AUST): Deakin University; 2017.
49. Ananthapavan J, Sacks G, Brown V. *Assessing Cost-effectiveness of Obesity Prevention Policies in Australia 2018 (ACE-Obesity Policy)*. Melbourne (AUST): Deakin University; 2018.

Supporting Information

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

Supplementary File: Additional information.