Government of **Western Australia**
Department of **Health**

The burden and cost of excess body mass in Western Australian adults and children

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Abbreviations

ABD	Australian Burden of Disease
AUD	Australian dollars
AIHW	Australian Institute of Health and Welfare
BMI	Body mass index
DALY	Disability adjusted life year
DRG	Diagnosis related group
GBD	Global Burden of Disease
HWSS	Health and Wellbeing Surveillance System
ICD	International Classification of Diseases
ICD10-AM	International Classification of Diseases, 10th edition Australian modification
LCI	Lower confidence interval
PAF	Population attributable fraction
RR	Relative risk
RSE	Relative standard error
TMRED	Theoretical minimum risk exposure distribution
UCI	Upper confidence interval
YLD	Years lost to disability
YLL	Years of life lost
WA	Western Australia
WHO	World Health Organization

Executive Summary

Introduction

In 2018, just over 70 per cent of Western Australian adults were estimated to be living with overweight or obesity.[1] One in four Western Australian children were overweight or obese,[2] placing them at an increased risk of obesity in adulthood.[3, 4]

Adult obesity in Western Australia (WA) has risen steadily from 21 per cent in 2002 to 32 per cent in 2018.[1] Nationally, the number of adults living with very severe obesity has increased by nearly one-third since 2014–15.[5]

Excess body mass resulting from the excess accumulation of body fat increases the risk of a range of chronic diseases and is an important cause of preventable illness and premature death.[6, 7] Excess body mass therefore incurs significant personal and societal costs. In 2011, it was estimated that excess body mass was responsible for 5.3 per cent of the total health burden in WA due to disability and years of life lost due to premature disease.[8]

To guide policy decisions for health services and public health planning, up-to-date estimates of the burden and cost of excess body mass to the WA health system are essential.

This report applies a methodological approach based on the *Global Burden of Disease Study*[6] and the *Australian Burden of Disease Study*[7, 9] to describe the burden and cost of hospitalisations in WA in 2016 and mortality in 2015 that is attributable to excess body mass. The potential impacts of excess body mass in a decade's time are also predicted, and an estimate of the burden and costs that could be avoided if the prevalence of excess body mass were to stabilise or to reduce, in comparison to the current increasing trend continuing.

This study advances the methods applied in a previous analysis of WA hospitalisation costs in 2011[10] by counting the impact of a greater number of diseases attributable to excess body mass and applying updated information on the risk of chronic diseases due to excess body mass to WA population health data. It is the first study to estimate the impact of excess body mass on hospitalisations among both children and adults living in WA.

The costs provided in this report provide a robust estimate of direct inpatient admission costs only. Costs from emergency department presentations, pharmaceutical costs, and outpatient health care costs are not included. The costs estimated in this study represent a portion of the total health system costs and do not include personal costs to individuals or costs to the community and economy, such as labour and productivity losses.

Key findings

- In 2016, 9.3 per cent of all hospitalisations for adults and children in WA were attributable to excess body mass and cost the WA health system $338.7 million ($AUD 2015–2016) or 6.1 per cent of all hospitalisation costs.
- More males were hospitalised due to conditions linked with excess body mass than females in 2016.
- The greatest number of hospitalisations attributable to excess body mass in 2016 were for chronic kidney disease due to diabetes mellitus, glomerulonephritis, hypertension, and other causes, totalling 70,203 hospitalisations or 70.4 per cent of all hospitalisations attributable to excess body mass.
- The linked diseases responsible for the greatest hospitalisation costs attributable to excess body mass were (in decreasing order): ischaemic heart disease; obesity; osteoarthritis of the knee; chronic kidney disease (all causes combined); gall bladder and biliary disease; and diabetes mellitus, totalling $242.7 million or 72 per cent of hospitalisation costs attributable to excess body mass in 2016. These are predicted to remain the costliest conditions attributable to excess body mass in 2026, whether current trends in overweight and obesity remain stable, are halted, or are reduced.
- In 2015, there were 1,174 deaths attributable to excess body mass, making up 8.1 per cent of all deaths in WA (no deaths in children were attributable to excess body mass in 2015).
- Adult males were more likely to die at a younger age (40 to 69 years) due to conditions linked with excess body mass than females, in 2015.
- The majority (63.9%) of deaths attributable to excess body mass in 2015 were due to ischaemic heart disease (29.9%), Alzheimer’s disease and other dementias (13.1%), diabetes mellitus (11.2%), and chronic kidney disease due to diabetes mellitus, hypertension and other causes excluding glomerulonephritis (9.6%) as principal causes of death.
- If current trends in child and adult overweight and obesity continue, the number of hospitalisations attributable to excess body mass in 2026 is predicted to increase by 54 per cent. Hospitalisation costs will rise by 80 per cent, to $610.1 million.
- If current trends in child and adult overweight and obesity continue, chronic kidney disease (all causes combined), diabetes mellitus, osteoarthritis of the hip, liver cancer, atrial fibrillation and flutter, Alzheimer's disease and other dementias, and gout are each predicted to incur more than 100 per cent growth in hospitalisation costs attributable to excess body mass between 2016 and 2026. Chronic kidney disease (all causes combined) and obesity (as a principal diagnosis) will overtake ischaemic heart disease to incur the greatest hospitalisation costs attributable to excess body mass.

- If the World Health Organization (WHO) target of halting the rise in overweight and obesity were to be achieved in WA, there would be a cost saving of $40.5 million (12%) in costs for associated hospitalisations in 2026 compared to costs if current trends in overweight and obesity continue.
- Applying a scenario whereby all adults with overweight or obesity in WA in 2016 reduced their body mass index (BMI) by 1 kg/m^2 would translate to a cost saving of $95.6 million (or 28%) in 2026 compared to current trends in excess body mass continuing.
- The number of adult deaths attributable to excess body mass are projected to increase by 32 per cent (376) in 2026 from 1,174 deaths in 2015, if current trends in overweight and obesity continue.
- Twelve per cent (146) fewer adult deaths attributable to excess body mass are predicted to occur in 2026 if rises in overweight and obesity were to be halted.
- Thirty per cent (352) fewer adult deaths attributable to excess body mass are predicted in 2026 if all adults who were overweight or obese in 2016 were to reduce their BMI by 1 kg/m^2.

Conclusions

Excess body mass is a significant contributor to hospitalisation costs and mortality in WA. If population levels of overweight and obesity continue to climb, it is projected that the cost to the WA health system will increase by 80 per cent in the decade between 2016 ($338.7 million) and 2026 ($610.1 million). This is an under representation of the full costs of excess body mass to the WA health system and to individuals, communities, and the WA economy. By comparison, significant cost savings could be made if the population prevalence of overweight and obesity were to stabilise or reduce.

The projected burden and costs of excess body mass indicate a strong potential for return on investments in publicly funded obesity prevention and early intervention programs, backed by robust policies and regulatory options to support Western Australians to achieve and maintain a healthy weight.

Introduction

Excess body mass resulting from the accumulation of fat mass increases the risk of a range of chronic diseases, including heart disease, stroke, type 2 diabetes, several types of cancer, and is an important cause of preventable illness and premature death.[6, 7] Excess body mass therefore causes significant personal, health care, and societal costs.

Excess body mass results from sustained energy intake that exceeds the body's requirements. An inter-play of lifestyle, environmental, psychological, metabolic, and genetic factors determines individual energy intake. Obesogenic environments, in which highly palatable, energy-dense, nutrient-poor, ultra-processed foods are inexpensive, readily accessible and heavily promoted, are a major factor in driving the rising levels of obesity in Australia and globally.[11] Owing to their ubiquitous nature, obesogenic environments promote weight gain and make maintenance of a healthy weight challenging for whole populations.

Body mass index[i] (BMI) is used to identify excess body mass in adults and children and is a valid measure for monitoring population levels of overweight and obesity.[12, 13] BMI is classified into underweight, healthy weight, overweight, and obese categories, based on associated comorbidity risk (**Table 1**).

Table 1. Classification of adult body weight according to body mass index (BMI).

Weight Category	Adult BMI	Risk of comorbidities
Underweight	<18.5	Low (but risk of other clinical problems increased)
Healthy weight	18.5 – 24.99	Average
Overweight	25 – 29.99	Increased
Obese		
Class I	30 – 34.99	Moderate
Class II	35 – 39.99	Severe
Class III	40+	Very severe

Source: World Health Organization.[12] The table shows a simple relationship between BMI and the risk of comorbidity, which can be affected by a range of factors, including the nature of the diet, ethnic group and activity level. The risks associated with increasing BMI are continuous and graded and begin at a BMI above 25.

It is well recognised that once gained, losing excess body mass is difficult and lost weight is often regained. This, combined with the multitude of chronic conditions linked to excess body mass, highlights the importance of public policies for obesity prevention as well as obesity management services. The World Obesity Federation[ii] defines obesity as a 'chronic relapsing disease process' that is a persistent condition that accompanies physiological changes and the development of ill health over time.[14] This definition was developed to signal the seriousness of

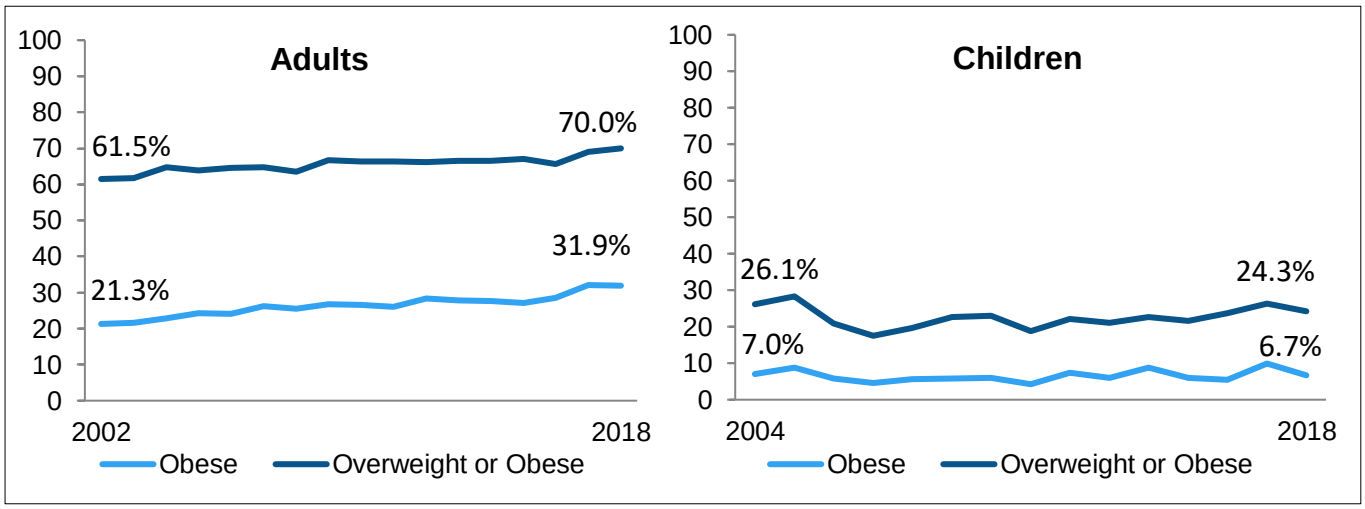
[i] Body mass index is calculated by dividing a person's weight (in kilograms) by their height (in metres) squared.
[ii] The World Obesity Federation is an international organisation that represents professional members of the scientific, medical and research communities dedicated to driving global efforts to reduce, prevent and treat obesity.

obesity as a health concern; stimulate healthcare investment in obesity management options; improve public health efforts to prevent obesity; and increase resources allocated to obesity management and prevention research.

Magnitude of the problem

In 2017, just over 70 per cent of Western Australian adults were estimated to be either overweight (38.5%) or obese (32.1%).[1] The prevalence of adults with obesity has risen steadily in Western Australia (WA) from 21 per cent in 2002 to 32 per cent in 2018 (**Figure 1**).[1] Although the prevalence of childhood overweight and obesity has not changed significantly in WA since 2004, one in four WA children aged 5–15 years were estimated to be living with overweight (17.6%) or obesity (6.7%) in 2018,[2] placing them at an increased risk of obesity and premature chronic disease in adulthood[3, 4] (**Figure 1**).

Figure 1. Trends in overweight and obesity in adults and children in Western Australia.



Source: Western Australian Health and Wellbeing Surveillance System[iii].

Across Australia, the prevalence of overweight and obesity is similar. In 2017–18, 67 per cent of Australian adults were above a healthy weight (12.5 million people), up from 56 per cent in 1995.[5] Most of this increase is due to growth in the number of adults who are obese, which has increased from 19 per cent in 1995 to 31 per cent in 2017.[5, 11] Australia-wide, at least 5.8 million adults are estimated to be living with obesity.[5, 11] The national statistics for children are similar to those for WA, and have been relatively stable for the past decade, with approximately one in four children aged 2 to 17 years in Australia identified as overweight (16.8%) or obese (8.1%) in 2017.[11] However, the proportion of 2 to 17 year olds living with obesity grew from 7 per cent in 2011–12 to 8.1 per cent in 2017–18, equivalent to an additional 24,500 children per year.[15] Nationally, the prevalence of excess body mass is highest in older age groups. In 2017-18, 78 per cent of 65 to 74 year olds were overweight or obese, placing an additional burden on the health status and care of Australia's aging population.[5]

[iii] Data sourced from successive reports from the WA Health and Wellbeing Surveillance System. Available from: https://ww2.health.wa.gov.au/Reports-and-publications/Population-surveys

Concerningly, the number of adults living with very severe obesity (BMI of 40+) is estimated to have increased by nearly one-third since 2014–15, from 570,000 to 740,000 adults.[5] The health care costs associated with very severe obesity are estimated to be more than double that of class I obesity (BMI 30 to 34.9).[16] This includes increased demand for specialist bariatric equipment and surgery. The number of adults undergoing bariatric surgery in WA increased from 1,736 in 2005-6 to 3,995 in 2010–11.[17] While the majority of bariatric surgery was performed in private hospitals, the number performed in WA's public hospitals tripled during this period.[17]

Inequities in overweight and obesity

Overweight and obesity disproportionately affect the socioeconomically disadvantaged, people living outside metropolitan areas, and Aboriginal and Torres Strait Islander Australians.[5] Australians living in outer regional and remote areas have higher rates of overweight and obesity than those living in inner regional areas and major cities.[18] Australians living in areas of greatest socioeconomic disadvantage are more likely to be overweight or obese than those living in areas of less socioeconomic disadvantage.[18] These geographical and socioeconomic disparities in overweight and obesity prevalence are more marked among children and adolescents.

According to the *2018-2019 National Aboriginal and Torres Strait Islander Health Survey*, Aboriginal and Torres Strait Islander adults were 1.2 times more likely to be overweight or obese and 1.6 times more likely to be obese, than non-Indigenous adults.[5, 19] Aboriginal and Torres Strait Islander children aged 2 to 14 years were more likely to be overweight or obese (37%) than their non-Indigenous counterparts (25%). There were even greater disparities seen in adolescents aged 15 to 17 years, with 42 per cent of Aboriginal and Torres Strait Islander adolescents identified as overweight or obese, including 18 per cent living with obesity, compared to 27 per cent and 9 per cent respectively, in their non-Indigenous counterparts.[5, 19]

Aims of this study

The Final Report of the *WA Sustainable Health Review* (2019)[iv] observed that obesity is having an increasing impact on Western Australians and undermining the long-term sustainability of the State's health system due to its contribution to chronic diseases.[20] In addition to hospital and broader health care costs, the burden of illness and premature death caused by overweight and obesity affects quality of life for individuals, families and carers, and workplace productivity. Given the relapsing nature of obesity and the range of chronic diseases linked with it, monitoring its burden and associated costs is critical.

The Western Australian Department of Health (the Department) is responsible for the overall management and strategic direction of the WA health system, and in ensuring the delivery of

[iv] The Sustainable Health Review was announced by the Government of Western Australia in June 2017. The purpose of the Review, which published its final report in April 2019, was to inform future decisions about the way that health is managed and delivered to ensure that Western Australians are receiving quality healthcare that can be sustained for our future generations (page 48). (https://www.mediastatements.wa.gov.au/Pages/McGowan/2017/06/Sustainable-Health-Review-to-position-WA-health-system-for-the-future.aspx)

high quality, safe and timely health services. The Department also has a fundamental role in disease prevention at the population level, setting strategic vision and state-wide policy, funding population health promotion programs, and developing and strengthening partnerships for prevention. To guide the Department's policy decisions for obesity prevention, obesity management and health service planning and funding, up-to-date estimates of the burden and costs of excess body mass to the WA health system, are essential.

The aim of this study was to generate comprehensive, up-to-date estimates and projections of the burden of excess body mass in Western Australian adults and children and its cost to the WA health system, to help guide the Department's policy decisions for obesity prevention and service planning.

Background

Burden of disease studies

Burden of disease studies are used to assess and compare the fatal and non-fatal impacts of different diseases, injuries, and risk factors on a population, using several indicators. These indicators can be used to monitor population health, guide health planning, and estimate the proportion of disease burden that could be prevented through the reduction of associated risk factors (attributable burden), including excess body mass.[8]

Years of life lost (YLL) is a measure of premature death (fatal burden) quantified as the number of years that death occurred before the expected lifespan calculated at the time of birth. Years lost to disability (YLD) is the number of healthy years lost to disability (non-fatal burden) through living with ill health due to illness or injury, weighted for disability severity.[9] Disability adjusted life years (DALYs) combines the burden from YLL and YLD, with one DALY equivalent to one year of healthy life lost.

Comparative risk assessment methodology is used to evaluate the predicted changes in population health which may result from modifying the population distribution of exposure to a risk factor or a group of risk factors. This methodology has been used in the *Global Burden of Disease (GBD) Study*[6] and the *Australian Burden of Disease (ABD) Study.*[7, 9]

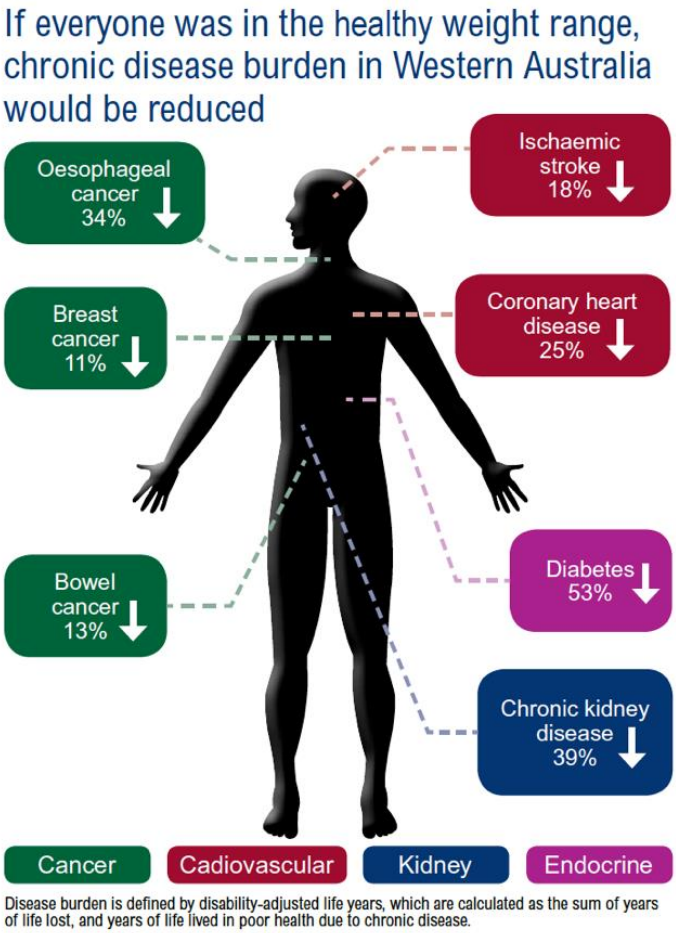
The *2016 GBD Study* examined 84 behavioural, environmental and occupational factors and clusters of risk factors including excess body mass (i.e. high BMI defined as BMI greater than 25 kg/m^2), to provide a comprehensive assessment of global risk factor exposure and attributable burden of disease between 1990 and 2016.[6] It estimated that high BMI was accountable for approximately 4.5 million (2.9 million to 6.4 million) deaths and 135.4 million (88.6 million to 187.4 million) DALYs globally in 2016. High BMI ranked fifth among risk factors for mortality, primarily due to the effect of high BMI on cardiovascular disease.

The Australian Institute for Health and Welfare (AIHW) *ABD Study* estimated that 7 per cent of the total burden of disease and injuries (calculated in DALYs) in Australia was attributable to overweight and obesity in 2011.[7] This included disease burden attributable to excess body

mass for 22 conditions in adults and for one condition (asthma) in children. DALYs due to excess body mass among people living in the poorest socioeconomic circumstances were 2.3 times higher than those in the living in the highest socioeconomic group. It was estimated that 6 per cent of future disease burden due to excess body mass in adults and children in 2020 could be avoided if there were no increases in overweight and obesity in the population and the 2011 prevalence was maintained.[7]

Applying the 2011 *ABD Study* methodology to WA, excess body mass was estimated to be responsible for 5.3 per cent (22,998 DALYs) of the total health burden, ranked third behind tobacco (7.9%) and alcohol (5.6%) use in 2011.[8] Over half (53%) of the burden from diabetes (types 1 and 2), 49 per cent of the burden from hypertensive (ischaemic and coronary) heart disease, 39 per cent of chronic kidney disease burden, and 34 per cent of oesophageal cancer burden could be avoided if everyone in WA had a healthy weight (**Figure 2**).

Figure 2. Chronic disease burden attributable to excess body mass, Western Australia 2011.



Source: WA Department of Health; Australian Burden of Disease Study (2011) unpublished data supplied by the Australian Institute of Health and Welfare.

Cost of illness studies

Cost of illness studies aim to evaluate and measure the economic burden of health problems on society. These studies build on burden of disease studies and can assist more directly with healthcare planning and in providing financial justifications for preventive interventions and thus, are critical tools for planning and guiding health policy. Costs of illness studies are usually limited to direct healthcare related costs such as medical costs associated with physician visits, diagnostic tests, hospitalisations and rehabilitation. However, they can also include comprehensive estimates of direct non-healthcare costs (e.g. costs associated with patient transport, informal care and relocation) and indirect costs (e.g. productivity losses due to morbidity and/or early mortality).

Based on the type of epidemiological data used, cost of illness studies can be prevalence-based ('top-down' approach or population-based) or incidence-based ('bottom-up' approach or person-based). Both methods have been used to estimate healthcare costs associated with excess body mass.[21] In the top-down approach, using data on the prevalence and relative risks of obesity-associated health conditions, population attributable fractions (PAFs) are first estimated for each health condition; these PAFS are then applied to the overall costs for these conditions to calculate costs attributable to obesity.[22] In the bottom-up approach, cross-sectional or longitudinal datasets are used wherein individual level BMI measurements are linked to health-related outcome datasets and/or other illness-related measures such as absenteeism; these input units are then multiplied by the unit costs of each health input.[22] The top-down approach provides policy makers with the overall magnitude of the economic impact of the illness to society and therefore, highlights the importance for prevention. The bottom-up approach is a more robust method to identify individual drivers of costs, but it is more resource intensive than the top-down approach. More recently, modelling studies have been used to predict the projected preventable burden and costs for medical conditions attributed to excess body mass costs for hypothetical cohorts of individuals over time.[23]

Several cost of overweight and/or obesity studies have been carried out in Australia. Due to differences in the methodological approaches, including differences in the type of health status, health outcomes and costs being evaluated, there is considerable heterogeneity in the costs estimated in each of the studies. For example, using the top-down approach, a study conducted by Access Economics for Diabetes Australia estimated the total direct and indirect cost of obesity to be AUD $3.8 billion in 2005, of which AUD $873 million was borne directly by the health system.[24] Colagiuri and colleagues used the bottom-up approach and estimated that in 2005, the total direct costs (mainly hospitalisation, medication, and ambulatory services costs) in Australia were AUD $6.5 billion and AUD $14.5 billion for overweight and obesity respectively, among adults aged ≥30 years.[25] In 2008, using updated prevalence data and a revised methodology, Access Economics estimated total obesity-related costs to be AUD $8.3 billion in Australia with an estimated AUD $833 million in Western Australia.[26] In 2015, combining the bottom-up approach with linear modelling, Black and colleagues demonstrated that among children aged 6 to 13 years, non-hospital Medicare costs were 28 per cent more per

year per child in children who were overweight or obese compared to children with a healthy BMI.[27] It was estimated that the total cost incurred by the Australian Government was AUD $43 million per year in 2015.[27]

In Western Australia, using the top-down approach, the direct costs to the health care system was estimated to be AUD $241 million (valued in 2011/2012 AUD) or 5.4 per cent of all acute hospital expenditure in 2011.[10] Through regression modelling, Scalley *et al* predicted that if trends in costs, hospital admissions, and population body weight were to continue unchanged, then acute hospital costs attributable to excess body mass would double from $241 million in 2011 to $488.4 million in 2021, an increase of 102.6 per cent.[10] However, the study included only adults aged over 30 years and the burden of excess body mass among children was not estimated.

This study aims to estimate the burden and cost of excess body mass in Western Australian adults and children. This study builds on the previous Western Australian study by using updated prevalence data, inclusion of an additional 18 health conditions partially or wholly attributable to excess body mass and using scenario modelling, to estimate a range of future trends. The specific objectives of this study are to:

1. Determine the hospital admissions and hospitalisation costs attributable to excess body mass in adults and children in Western Australia in 2016, and deaths attributable to excess body mass in 2015. Cause of death data were not available for 2016 at the time of this study.
2. Use scenario modelling to estimate the hospital admissions, hospitalisation costs, and deaths attributable to excess body mass in 2026.

Methods

Overview

Hospitalisations and deaths attributed to excess body mass in adults and children in WA were estimated in this study using an updated comparative risk assessment methodology. Scenario modelling was used to estimate hospital admissions, hospitalisation costs, and deaths attributable to excess body mass in 2026 under three scenarios:

- **Trend scenario**: the current trend in prevalence of excess body mass in adults and children continues unchanged.
- **Stable rate scenario**: the rise in prevalence of excess body mass in adults and children is halted, with the prevalence of excess body mass in 2026 remaining the same as 2016.
- **Reduced scenario**: the adult population with excess body mass in 2016 reduced their BMI by 1.0 and these rates are maintained in 2026.

The following steps were undertaken:

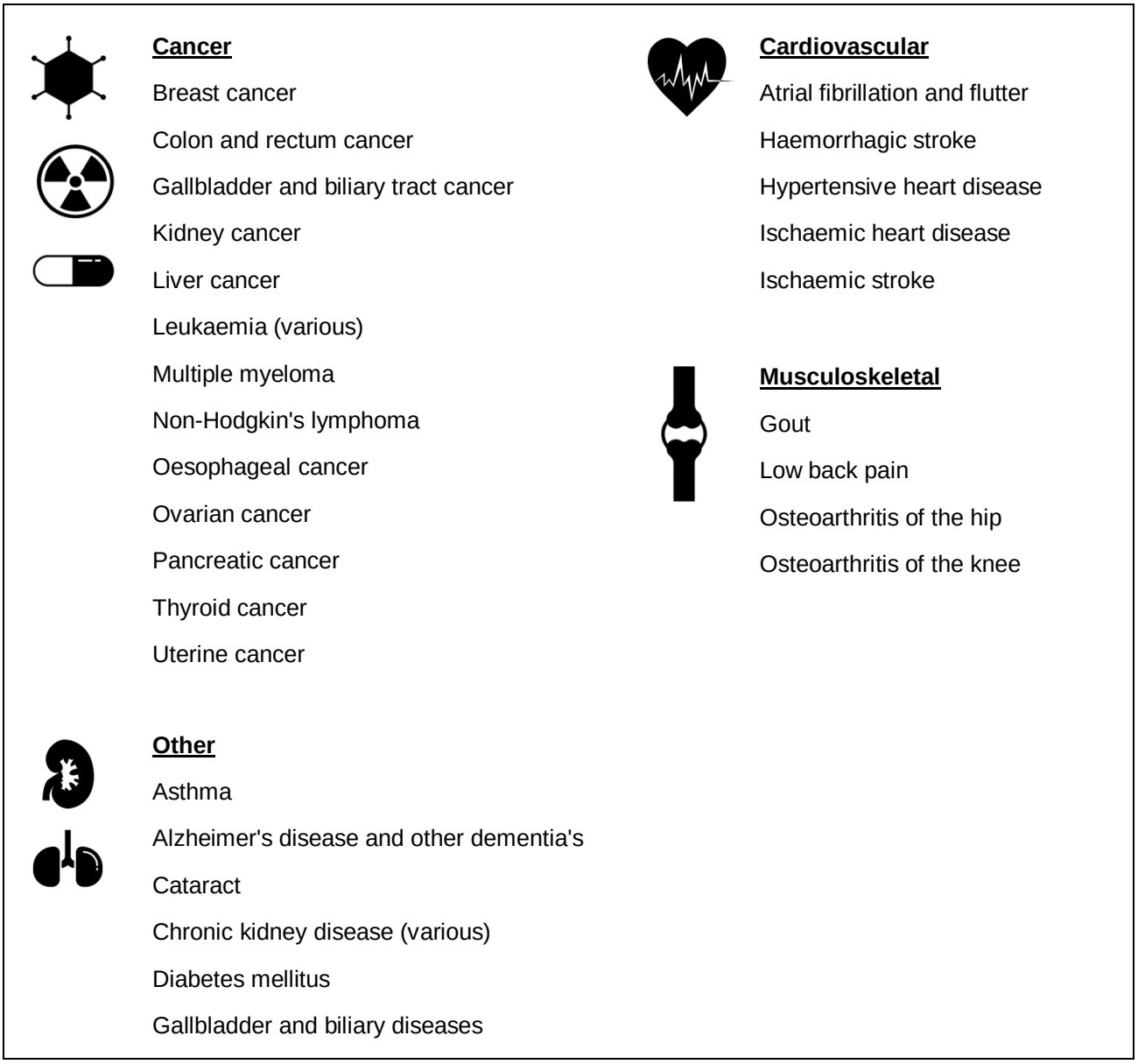
1. Identification of medical conditions linked to excess body mass (linked diseases).
2. Estimation of the population-level distribution of excess body mass (risk factor exposure) in the WA population for 2016.
3. Sourcing of estimates of the effect size for the relationship between excess body mass and each linked disease (relative risks).
4. Definition of the counterfactual, the theoretical minimum risk exposure distribution (TMRED) for excess body mass (TMRED is explained below).
5. Calculation of the population attributable fractions (PAFs) for excess body mass for 2016, the study reference year. The PAF is defined as the fraction of all cases of a particular disease or other adverse condition in a population that is attributable to a specific risk factor exposure.[28]
6. Application of PAFs to hospitalisations and hospitalisation costs for 2016 and to deaths for 2015.
7. Projection of risk factor exposure in the WA population for 2026 for three different scenarios.
8. Calculation of PAFs for 2026 for three different scenarios using projected 2026 risk factor exposure.
9. Projection of hospitalisations, deaths and hospitalisation costs for 2026 and application of 2026 PAFs to these projections for the three different scenarios.

Ethical approval for this study was granted by the WA Department of Health's Human Research Ethics Committee (reference number 2016/52) and the Western Australian Aboriginal Health Ethics Committee (reference number 741), as part of the *WA Burden of Disease Study* ethics application.

Linked diseases

Linked disease is the collective term used in this study to identify diseases for which there is evidence that the probability of its occurrence is increased from exposure to excess body mass i.e. the disease can be attributed to excess body mass. Linked diseases were included in this study where they were partially or wholly attributed to excess body mass. The full list of linked diseases used in this study is given in **Figure 3.**

Figure 3. Linked diseases included in study.



All thirty-five diseases linked to excess body mass in the *2016 GBD Study* were analysed in this study.[6] This included medical conditions for which there was convincing or probable evidence of a causal relation between a risk factor and a health outcome according to World Cancer Research Fund grades of evidence.[6] In addition, hospitalisations and deaths where 'obesity' was the principal diagnosis or cause of death were included in the present study. Hospitalisations for 'drug induced obesity' were excluded.

Hospitalisations with a principal diagnosis for a linked disease in 2016 were identified using the International Classification of Disease Australian Modification (ICD-AM) 9th edition. The *2016 GBD Study* used ICD-10 codes and these were adapted to the ICD-10-AM 9th edition by the WA Clinical Coding Authority. Additional checks were completed to ensure the appropriateness of each code and to ensure no codes for linked diseases were omitted. For the purpose of modelling projections, the ICD-10-AM 9th to 5th editions were used to identify hospitalisations between 2007 and 2016. To identify deaths caused by a linked disease, ICD-10 codes used by

2016 GBD Study were used as there is no specific Australian modification for cause of death. Full lists of the ICD-10 and ICD-10-AM codes used in this study are given in **Table A.2**.

Several other medical conditions and diseases have been linked to excess body mass, such as infertility, depression and sleep apnoea. Relative risks for these conditions were unavailable at the time of this study. Excess body mass is also known to increase the rates of complications for a number of surgical procedures and medical treatments however, established methodology on how to include this burden was not available at the time of this study and so these outcomes are not included.

Adjustments for specific linked diseases

Renal dialysis hospitalisations were assigned to four subgroups according to their underlying cause of chronic kidney disease (diabetes, hypertension, glomerulonephritis, and other causes), using rates from the Western Australian subset of the Australia and New Zealand Dialysis and Transplant Registry for 2015[v]. Rates of each underlying condition in those who present to hospital and satellite dialysis-based services were determined by age and gender groups. Condition- and age-specific relative risks for chronic kidney disease due to these four underlying causes were then used to calculate PAFs.

Congestive heart failure is known to be increased in those with excess body mass however, in this study it is not considered a separate disease but rather included as a consequence of other cardiovascular diseases such as hypertensive heart disease and ischaemic heart disease. Similarly, endometrial cancer is not included as a separate disease but is combined with the linked disease ovarian cancer.

The *2016 GBD Study* used adjusted relative risks for oesophageal cancer and included an ICD-10 code that does not differentiate oesophageal carcinoma by morphology; this study uses the same method.[6]

Evidence suggests that overweight in pre-menopausal women may be a protective factor for breast cancer, however high BMI has been significantly associated with larger tumour size, increased vascular infiltration, and increased risk of metastasis to axillary lymph nodes.[29] In view of the uncertainty around the impact of high BMIs on the incidence and prognosis of breast cancer in pre-menopausal women, this study focuses on breast cancer in the post-menopausal age group.

In this study, age groups were restricted to those 65 years and above for Alzheimer's disease and other dementias, as in the *ABD Study.*[7]

[v] ANZ Dialysis and Transplant Registry (ANZDATA). About ANZDATA. Available from: http://www.anzdata.org.au/v1/structure.html [accessed 20/05/2019].

Determining population attributable fractions

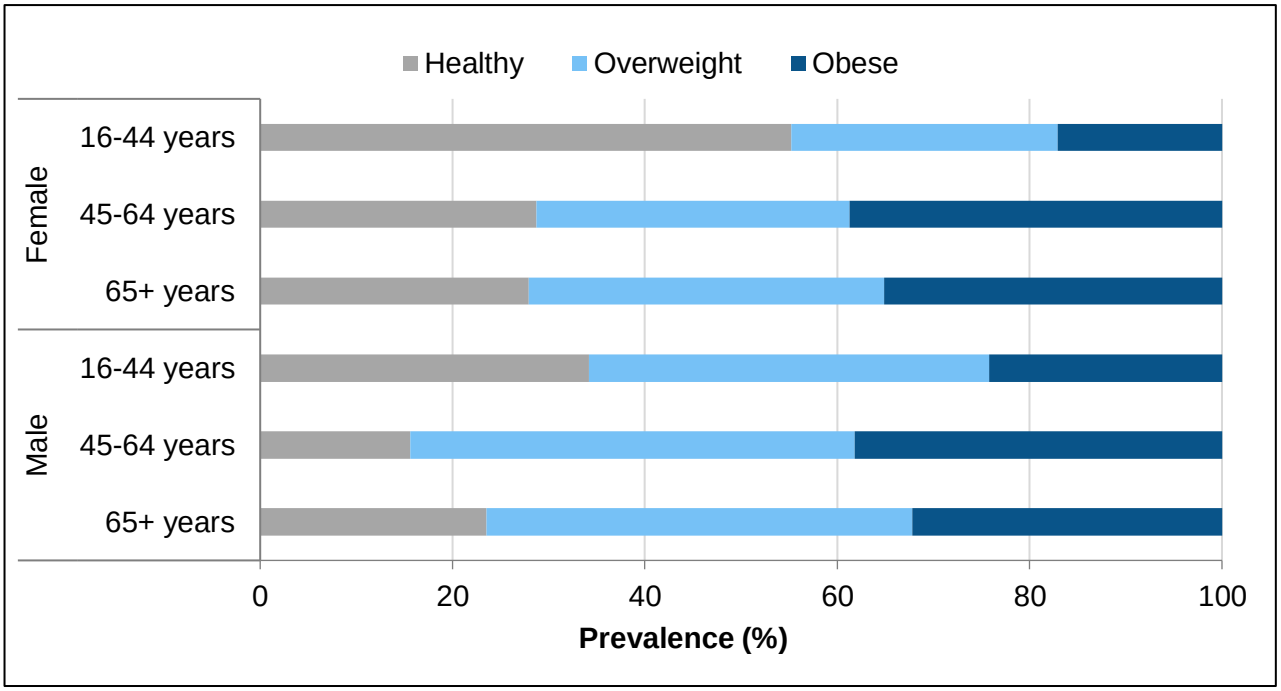
Prevalence of excess body mass in the Western Australian population

Except for individuals with a very high muscle mass (e.g. elite athletes, body builders), BMI is a reliable proxy for excess body fat in adults[13] and children.[30]

Excess body mass in adults (18 years +) was defined in this study as having a BMI of 25 or more (**Table 1**).[12, 16] In healthy children and adolescents, BMI changes substantially with growth and exhibits sexual dimorphism during puberty. Age- and sex-specific BMI cut-off points were therefore applied to enable comparisons of trends of excess body mass in children.[30] Excess body mass was defined in this study as having a BMI above the age- and sex-specific cut-off for a healthy BMI in children (up to the age of 18 years).

The prevalence and distribution of excess body mass in adults and children in the WA population was sourced from the Department of Health's Health and Wellbeing Surveillance System (HWSS), a continuous survey that has monitored the health and wellbeing of the WA population since 2002.[31, 32] Interviews are conducted via Computer Assisted Telephone Interviews (CATI) with households selected at random from the 2013 White Pages by a stratified random process with over-sampling representative of the population in rural and remote areas. The HWSS is weighted to the WA population to ensure the representativeness of survey results.[31, 32] The average participation rate in 2016 for adults and children was over 90 per cent.[31, 32] Adult prevalence estimates of BMI in the HWSS are calculated using self-reported height and weight. The HWSS applies an adjustment factor to account for limitations due to self-reporting, as described by Hayes *et al*.[33] The prevalence of healthy weight, overweight and obesity for WA adults in 2016 is shown in **Figure 4**.

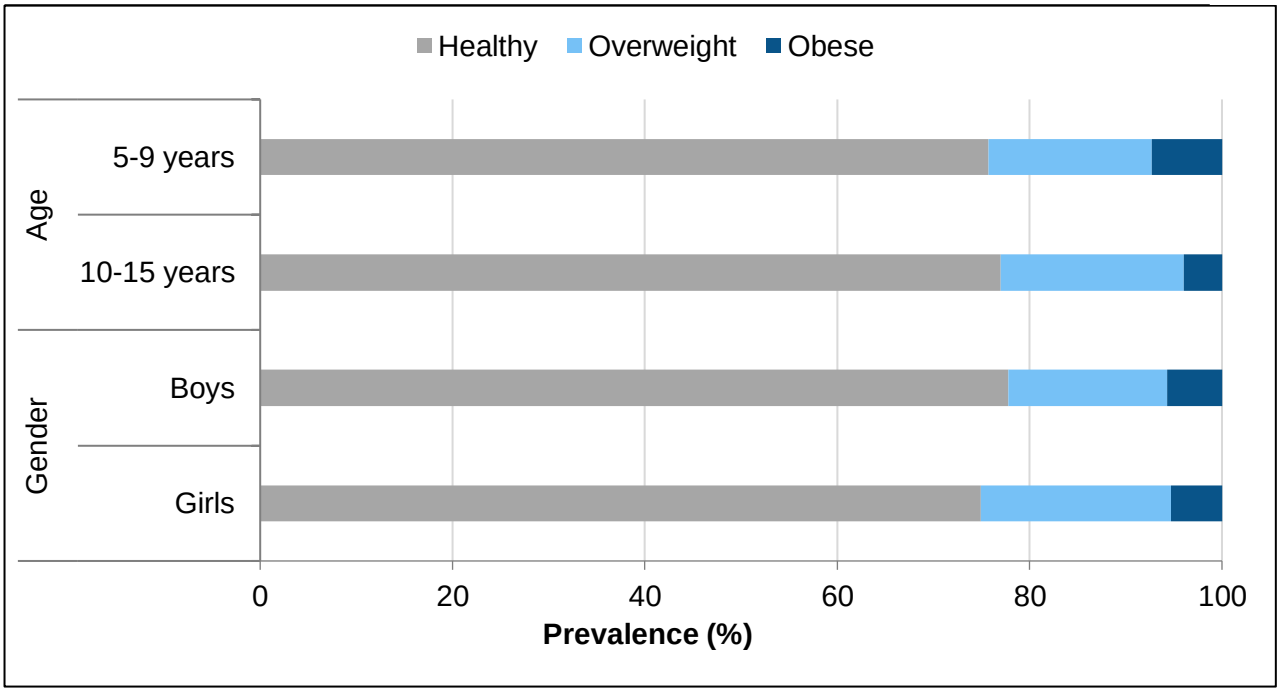
Figure 4. Weight status by age group and sex, Western Australian adults, 2016.



Source: Western Australian Health and Wellbeing Surveillance System[31]

For estimates of the prevalence of excess body mass in children, parents/carers were asked to provide their child's height (without shoes) and weight (without clothes or shoes). BMI was derived from these data and individual age- and sex-specific BMI cut-offs determined by Cole *et al*[30] were applied to categorise children into healthy weight, overweight, or obese. Figure 5 shows the prevalence of healthy weight, overweight, and obesity in WA children in 2016, by age group and gender.

Figure 5. Weight status by age group and sex, Western Australian children, 2016.



Source: Western Australian Health and Wellbeing Surveillance System[32]

For the purposes of this analysis, 13 categories or increments of adult BMI were created for each adult age and sex group. The categories were determined in the finest possible increments from the data source. To reduce the impact of survey error, data were extracted at a level where the majority of Relative Standard Errors (RSEs) were 25 per cent or less for each age- and sex-specific BMI category. However, this was not always possible, and some categories had RSEs of 25–50 per cent. Prevalence data required pooling of three years of HWSS survey data (2015–2017) to obtain relative standard errors within an acceptable range (<25%) for most age and risk factor categories for the reference years 2015 (deaths), 2016 (hospitalisations). Only two BMI categories were used for children: overweight and obese.

Relative risks

The relative risks for the associations between excess body mass and linked diseases in this study were used in the *2016 GBD Study* and obtained from a large number of prospective observational studies (see **Appendix 1, Table A.1.**).[6]

Relative risks were specific for high BMI (excess body mass) and each linked disease. For the linked diseases osteoarthritis, stroke, chronic kidney disease and leukaemia, relative risks were

broken down further by site and subtype e.g. hip and knee osteoarthritis. Sex-specific relative risks were available for some conditions. The availability of age-specific relative risks differed by condition. For the majority of linked diseases, relative risks were available for 5-year age groups starting from 20 years and up to 95+ years of age. However, for chronic kidney disease, relative risks were only available for the age groups: 30-59, 60-69, 70-79, and 80+ years. The only relative risk available for children at the time of this study was for asthma, and this is consistent with other studies that have estimated the burden of excess body mass in children.[7]

Relative risks for adults were reported as continuous variables, so that risk could be assigned according to graduating levels of exposure, i.e. per 5kg/m^2 increase in BMI. For children, relative risks for only two categories were used; obese and overweight.

Theoretical minimum risk exposure distribution

In this study the estimated contribution of excess body mass to hospitalisations and deaths was calculated by comparing the observed risk factor distribution with an alternative, hypothetical distribution (the counterfactual scenario). In their most recent studies, *GBD* and *ABD Studies* both use a theoretical minimum risk exposure distribution (TMRED) scenario.[6, 7] The TMRED is the risk factor exposure distribution that will lead to the lowest conceivable disease burden for a population and reflects the level of exposure where risk commences for each linked disease.[7]

This study focuses on attributable burden from excess body mass only and does not include burden from low body mass, which is known to be linked to a number of diseases and medical conditions. In this study a TMRED of 20–24.99 kg/m^2 was applied. This is the exposure range at which a person can be said to have a healthy BMI and is not at increased risk of developing related disease.[6, 34]

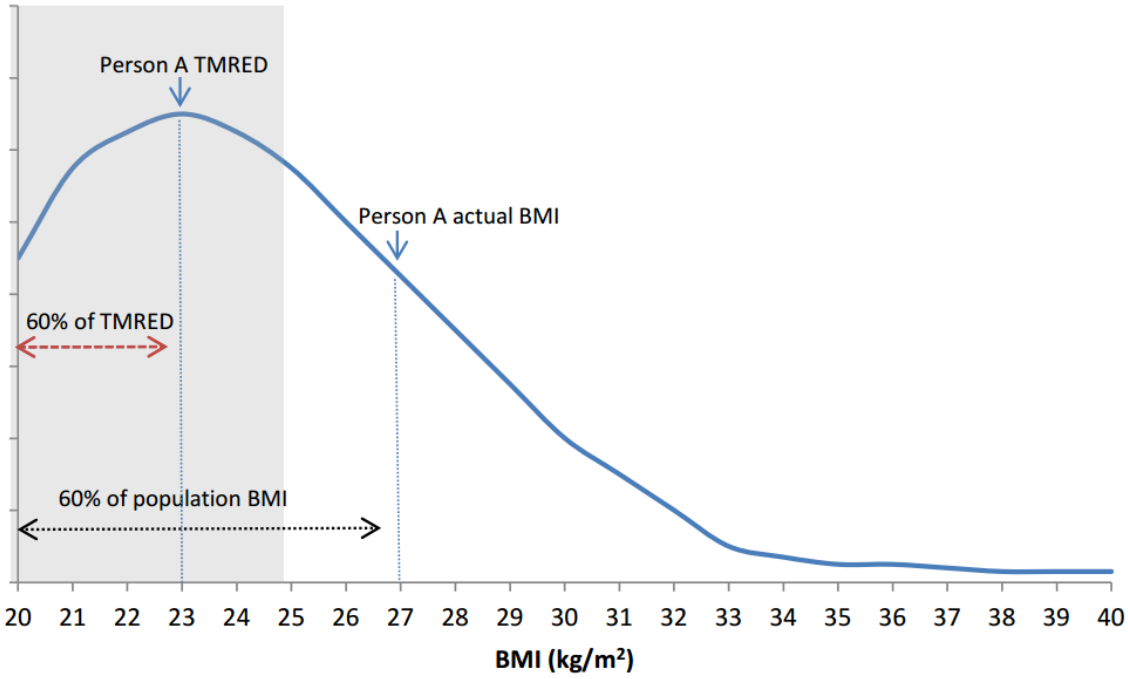
An updated model was used to estimate the appropriate TMRED value from within this range for each person, as used in the *ABD Study.*[7] This model takes into account the placement of a person's actual BMI within the BMI distribution of the WA population. Each person's lowest TMRED value depends on the placement of their actual BMI within the BMI distribution of the WA population, starting at 20 kg/m^2, as this is the lowest TMRED possible.

This model assumes that a healthy BMI is a range, as opposed to a single value for the entire population. The level of actual BMI compared to the TMRED value from within the range is used to calculate the level of risk of hospitalisation or death for each person in the population. An example of how TMRED is estimated, from the AIHW, is given in **Box 1**.[7]

The TMRED is used to determine which relative risks and prevalence data are used to calculate the PAFs for adults only. A TMRED is not applied to relative risk and prevalence data for children as only two categories are used which are assumed to be outside the healthy BMI range.

Box 1. Example of TMRED estimation for adults.

1. Person A has a BMI of 27 kg/m^2 and this BMI is greater than 60 per cent of the population's BMI.
2. The TMRED value for Person A is equal to 60 per cent of the possible TMRED values from within this range (20–25 kg/m^2) (TMRED distribution is assumed to be uniform).
3. The TMRED for person A is then a BMI of 23.
4. TMRED is then included as a value in the PAF calculation.



Shaded area in figure represents the TMRED, 20–25kg/m^2

Source: AIHW, 2017[7] (reproduced with permission from AIHW)

Calculation of population attributable fractions

The PAF is defined as 'the fraction of all cases of a particular disease or other adverse condition in a population that is attributable to a specific risk factor exposure'.[28] PAFs can be applied to estimates of disease burden, which may be quantified as DALYs, or as in this study, as hospitalisations and deaths. When applied to an estimated burden, it can be used to estimate the percentage of burden that would occur in a population due to that risk factor.

The components used to calculate PAFs for excess body mass in this study include:

- prevalence of excess body mass in the population (*P*)
- effect size, or relative risk (*RR*) of excess body mass on the linked disease of interest
- theoretical minimum risk exposure distribution (TMRED)

The following formula was used for the calculation of PAFs for children, where categorical data (overweight, obese) were available:

$$PAF = \frac{P(RR-1)}{P(RR-1)+1} \text{ x } 100$$

The following formula was used for the calculation of PAFs for adults, where continuous BMI data were available:

$$PAF = \frac{\sum_c P_c\,(RR_c - 1)}{\sum_c P_c\,(RR_c - 1) + 1} \text{ x } 100$$

Where: $\sum_c$ = the sum across all BMI categories and *c* = index for BMI category

The PAF for the linked disease 'obesity' was assumed to be 100 per cent. The sources used to calculate PAFs in this study are shown in **Table 2**.

Table 2. Summary of data used to calculate population attributable fractions in adults and children.

Age group	Prevalence data source	Relative risk source	TMRED source
Adults (20–85+ years)	Health and Wellbeing Surveillance System Adults 2015–2017 with 2016 as midpoint[31, 35, 36]	The Global Burden of Diseases, Injuries, and Risk Factors Study 2016[6]	Impact of overweight and obesity as a risk factor for chronic conditions, AIHW 2017[7]
Children (5–19 years)	Health and Wellbeing Surveillance System Children 2015–2017 with 2016 as the midpoint[3, 32, 37]		Not applicable

Quantifying attributable burden in 2016

The burden attributable to excess body mass was estimated by applying the calculated PAF for each linked disease to the number of hospitalisations or deaths for that disease. The following formula was used:

$$AB = PAF\ x\ T$$

Where:

AB = attributable burden (hospitalisation or death)
PAF = population attributable fraction for a specific linked disease
T = the total burden (total number of hospitalisations or deaths) for a specific linked disease

Attributable burden was calculated by sex and 5-year age-group for each linked disease.

Hospitalisations

The number of hospitalisations for each of the linked diseases for 2016 was identified from the WA Hospital Morbidity Data System (HMDS). This includes hospital separations (formal and statistical[vi]) from all private and public hospitals in WA. Hospital separations are referred to as hospitalisations in this report and include hospitalisations for WA residents only. Formal and statistical separations were not combined in this study.

Hospitalisation costs

Hospitalisation costs for linked diseases were sourced from the HMDS. Cost data included in this dataset was estimated using Diagnostic Related Group (DRG) costs assigned to each hospitalisation for all hospitals in WA. Hospitalisation costs for 2016 were estimated using a constant price index for 2016 as published by the AIHW.[38] For hospitals, the government final consumption expenditure index is used.[38] Indexes used for 2016 are given a value of 100 per cent for 2015–2016 as the 2016–2017 total health price index was not available at the time of this study.[38] All costs in this report are referenced to the 2015–2016 financial year and are in Australian dollars.

Deaths

The number of deaths for each of the linked diseases in 2015 were identified from the WA Death Registrations database. This database includes all reported deaths in WA by calendar year and ICD-10 code. Cause of death data were not available for 2016 at the time of this study.

Not all linked diseases result in death as an outcome. The following linked diseases were not used in attributable death calculations: low back pain, osteoarthritis of knee, osteoarthritis of hip, and gout. As for hospitalisations, only two linked diseases (asthma and obesity) were used to identify deaths attributable to excess body mass in children.

Quantifying attributable burden in 2026

The projected WA population in 2026 was identified using WA Department of Planning estimates.[39] At the time of this study and following adjustments according to the 2016 Census, band C projections (median population forecasts) were deemed to best fit the likely population for WA in 2026.[39] A number of assumptions are made in calculating these projections, including that the current fertility, mortality, and migration trends will continue.

Hospitalisations

Hospitalisation data from 2007–2016 were used to project hospitalisations for each linked disease by sex and 5-year age-group to the projected 2026 population using the exponential

[vi] **Formal separation**: The administrative process by which a hospital records the cessation of treatment and/or care and/or accommodation of a patient. **Statistical separation**: The administrative process by which a **hospital** records the cessation of an episode of care for a patient within the one hospital stay (AIHW).

weighted moving average method.[40] This technique places greatest weighting on the most recent years of data to guide projections.

Changes to ICD-10-AM coding of diabetes mellitus in mid-2010 decreased the scope of diabetes surveillance in WA. This decrease in surveillance was not a true reflection of diabetes occurrence in the WA population, but rather a change to the way it was coded in the hospitalisation data. To avoid a potential artefact, projections for diabetes mellitus were limited to using hospitalisations from 2011 to 2016 rather than a ten-year period as for other linked diseases.

Where the number of hospitalisations for subtypes of linked diseases was less than 5, these were combined to increase the numbers for the calculation of hospitalisations and costs (and deaths) where appropriate. Hospitalisations due to leukaemia were projected using all types grouped together (acute myeloid, chronic myeloid, acute lymphoid, chronic lymphoid, and other types) due to small numbers. This was possible as the relative risks for different types of leukaemia were the same.

Projections to 2026 were only calculated for linked diseases with 20 or more hospitalisations a year, to reduce instability from projecting small numbers.

Hospitalisation costs

In order to compare estimates of expenditure in different time periods (2016 and 2026), inflation needs to be compensated for in a process known as ‘deflation’. Deflators or ‘price indexes’ can be calculated in a number of different ways depending on the scope of the cost estimates, the area of health care, and the analytical purposes of the estimates.

Hospitalisation costs for 2026 were estimated using cost data from 2007–2016, which was adjusted for deflation using the government final consumption expenditure index published by AIHW.[38] As there has been positive health inflation in most years, prices in the years preceding the reference year are assumed to be lower than those applied in the reference year, 2016.

Hospitalisation costs for 2026 were estimated using a multiple linear regression model, with average costs modelled separately for each linked disease by sex and 5-year age group. A number of assumptions are made using this method for cost modelling, including:

- That the hospitalisation cost trends seen between 2007–2016 will continue.
- That the rate of hospitalisations will continue as seen between 2007–2016.
- That policy and economic factors stay the same.

Deaths

Death data for linked diseases from 2006–2015 were used to project deaths for linked diseases by sex and 5-year age groups using the same methods as described for hospitalisations. Deaths were not projected for a linked disease if there were less than 20 deaths across all age groups for either males or females in this time period, due to the instability of projecting such

small numbers. For this reason, death projections are not given in this report for: gallbladder and biliary tract disease; asthma; thyroid cancer; chronic kidney disease due to glomerulonephritis and hypertension; obesity; and gallbladder and biliary tract cancer. As there were less than 20 deaths from asthma or obesity between 2006-2015 in all child age groups, no projections were made for deaths attributable to excess body mass in children.

Projection Scenarios

Hospitalisations, hospitalisation costs, and deaths due to excess body mass were estimated for the year 2026 under three scenarios based on varying population prevalence of excess body mass. These scenarios were chosen to demonstrate the potential burden and cost to the WA health system that may be avoided if the increasing prevalence of excess body mass was halted or reduced, in comparison to if current trends continue. The projected burden and cost for 2026 was compared with the burden and costs calculated for 2016.

Trend scenario: ***the current trend in prevalence of excess body mass in adults and children continues unchanged.*** For this scenario, excess body mass prevalence data was projected to 2026 using linear regression of 10 years of historical data (six years of historical data for diabetes mellitus) and the projected population for 2026. This projection assumed that increases in excess body mass prevalence continue at the same rate to 2026 as over the previous ten years (2017-2016), and that current behaviours and public health interventions to reduce excess body mass do not change and will have the same impact on the population.

Stable rate scenario: ***the rise in prevalence of excess body mass in adults and children is halted, with the prevalence of excess body mass in 2026 remaining the same as 2016***. This scenario meets the World Health Organization's *Global Action Plan for the Prevention and Control of Non-communicable Diseases* target for 2025 of halting the rise in obesity[41] (extending to those who are overweight) and aligns with the *WA Sustainable Health Review* target to halt the rise in obesity in WA by July 2024.[20] Under this scenario, the prevalence of excess body mass in 2016 was applied to the projected population of 2026 to represent the effect of maintaining the prevalence of excess body mass at 2016 levels.

Reduced scenario: ***if the adult population with excess body mass in 2016 reduced their BMI by 1.0 kg/m^2 and this was maintained to 2026***. Under this scenario, the prevalence of excess body mass in 2026 was estimated after reducing the BMI of every adult in 2016 who was overweight or obese, by 1 kg/m^2 and applying this to the projected population for 2026. Children were excluded from this scenario as reductions in BMI are generally not recommended during periods of growth.[42]

For each scenario, the same linked diseases were used for 2026 as for 2016 and it was assumed that relative risks would remain unchanged between 2016 and 2026 to create PAFs for 2026.

Comparisons with other studies

There have been a number of developments in the methodology used in burden of disease estimations for risk factors such as excess body mass. Improvements in the evidence base for causal relationships between excess body mass and a number of diseases also means that a more accurate estimation of disease burden can be made.

The present study uses an updated technique used in the latest *GBD*[6] and *ABD*[7, 9] *Studies* for calculating the distribution in the population of those with the lowest risk from excess body mass – the theoretical minimum risk exposure distribution (TMRED).[7] However, the present study differs from the *GBD* and *ABD Studies* in that:

- PAFs were applied to linked disease hospitalisations and deaths rather than DALYs.
- An estimation of cost of the burden of disease attributed to excess body mass was made using DRG hospitalisation cost data.

The methods used in the present study also differ to those applied in the 2011 analysis by Scalley *et al,*[10] which analysed attributable hospitalisations, including emergency department presentations, for fewer linked diseases (18) and only in adults aged 30+ years.[10]

This study concentrates on direct inpatient admission costs and does not take into account costs from emergency department presentations, pharmaceutical costs, or outpatient health care costs.

The methodological updates applied in this study are summarised in **Box 2**. These variations in methodology mean that the estimates of attributable burden from excess body mass determined in this study are not directly comparable to the previous WA study by Scalley *et al* [9] or with the *GBD Study*[6] or *ABD Studies.*[6, 7, 10]

Box 2. Summary of methodological developments and updated data used in this study.

1. Updates in theoretical minimum risk exposure distribution (TMRED) calculation.
   - This study uses methodology used in the *ABD Study* to calculate TMRED.[7]
   - TMRED was updated to the range 20–25kg/m^2
   - TMRED calculation for each category of BMI was updated to include a new model which is based on the population distribution of BMI.
2. Inclusion of more linked diseases than the previous WA analysis by Scalley *et al.* [9]
   - This study included all 35 diseases linked to excess body mass used in the *2016 GBD Study*, which included conditions if they met the World Cancer Research Fund grades of 'convincing' or 'probable' evidence for a causal relationship,[6] in addition to obesity.
3. Exclusion of two linked diseases (included in other disease entities).
   - Endometrial cancer (ovarian cancer)
   - Congestive heart failure (ischaemic heart disease and hypertensive heart disease)
4. Subgroup analyses of four linked disease groups.
   - Stroke by type: haemorrhagic or ischaemic.
   - Chronic kidney disease by cause: diabetes, hypertension, glomerulonephritis, or other.
   - Leukaemia by type: acute myeloid leukaemia, chronic myeloid leukaemia, acute lymphoid leukaemia, chronic lymphoid leukaemia or other.
   - Osteoarthritis by site: hip or knee.
5. Extended age groups.
   - Inclusion of children and adolescents: addition of 5–9, 10–14 and 15–19 years age groups.
   - Linked diseases used in this study for children and adolescents were asthma and obesity.
   - Inclusion of young adults: addition of 20–29 years age group.
6. Extended categories of risk factor exposure.
   - Uses 13 different BMI categories for adults and 2 categories for children.
7. Updated prevalence data:
   - Uses estimation of exposure distribution data of excess body mass in children and adults estimated in 2016.
8. Updated relative risk data sourced from the *2016 GBD Study.*

Results

Burden due to excess body mass in 2016

This section presents estimates of hospitalisations and hospitalisation costs attributable to excess body mass in WA in 2016 (for adults and children) and estimates of deaths attributable to excess body mass in 2015 (for adults).

Attributable hospitalisations 2016

In 2016, a total of 262,351 hospitalisations occurred with a linked disease as the principal diagnosis. The proportion of hospitalisations for each linked disease that was attributable to excess body mass ranged from 5 per cent (ovarian cancer) to 100 per cent (obesity) (**Table 3**).

A total of 99,651 hospitalisations were attributed to excess body mass in 2016 (**Table 4, Table B.1**). This represents 38.0 per cent of hospitalisations for all linked diseases and 9.3 per cent of total hospitalisations for all conditions, including injury and disease, in 2016 (**Table 4**).

The greatest number of hospitalisations attributable to excess body mass were for chronic kidney disease due to diabetes mellitus (33,529), chronic kidney disease due to glomerulonephritis (14,572), chronic kidney disease due to hypertension (7,301) and chronic kidney disease due to other causes (14,801) (**Table 4**). Collectively, these conditions were responsible for 70.4 per cent of all hospitalisations attributable to excess body mass. This was followed by hospitalisations due to ischaemic heart disease (4,892) and obesity as a principal diagnosis (4,421).

The number of hospitalisations attributable to excess body mass was greater for males (52,061) than females (47,588). Hospitalisations attributable to excess body mass peaked at the ages of 65–69 years for males and at 60–64 years for females (**Figure 6, Table B.1**).

Figure 6. Hospitalisations attributable to excess body mass by age and sex, 2016.

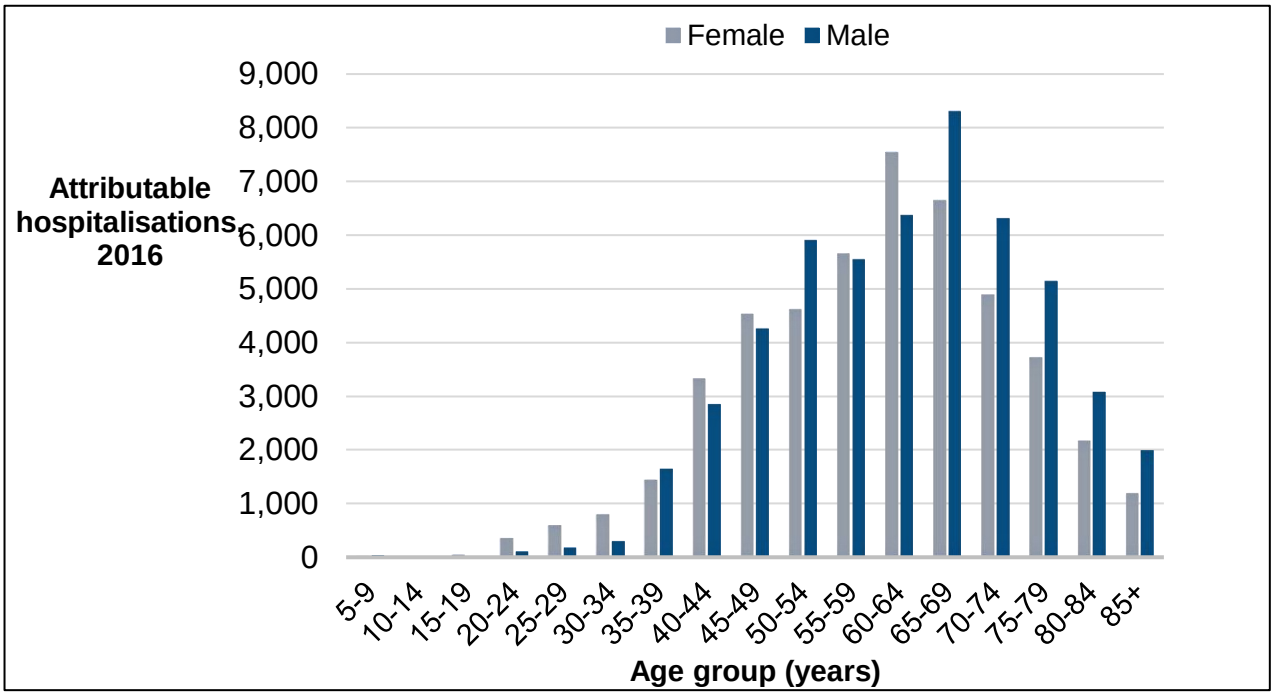


Table 3. Proportion of hospitalisations for a principal diagnosis of a linked disease attributable to excess body mass in 2016.

Linked disease	Proportion of hospitalisations for linked diseases attributable to excess body mass
Obesity	100 %
Diabetes mellitus	54 %
Hypertensive heart disease	53 %
Chronic kidney disease due to diabetes mellitus	50 %
Chronic kidney disease due to glomerulonephritis	47 %
Uterine cancer	46 %
Chronic kidney disease due to other causes	44 %
Gallbladder and biliary diseases	43 %
Chronic kidney disease due to hypertension	41 %
Gout	41 %
Haemorrhagic stroke	37 %
Oesophageal cancer	33 %
Osteoarthritis of the knee	33 %
Atrial fibrillation and flutter	30 %
Ischaemic heart disease	29 %
Liver cancer	25 %
Kidney cancer	24 %
Ischaemic stroke	24 %
Gallbladder and biliary tract cancer	23 %
Asthma	22 %
Thyroid cancer	18 %
Alzheimer's disease and other dementias	16 %
Colon and rectum cancer	13 %
Chronic myeloid leukaemia	13 %
Osteoarthritis of the hip	13 %
Acute myeloid leukaemia	12 %
Chronic lymphoid leukaemia	12 %
Low back pain	12 %
Cataract	12 %
Multiple myeloma	11 %
Other leukaemia	10 %
Pancreatic cancer	9 %
Breast cancer	9 %
Non-Hodgkin's lymphoma	9 %
Acute lymphoid leukaemia	6 %
Ovarian cancer	5 %

Table 4. Number of attributable hospitalisations and deaths in 2015/2016 and 2026 for adults and children under three scenarios.

Linked disease	Attributable hospitalisations				Attributable deaths			
	2016	2026			2015[a]	2026 [b,c]		
		Trend	Stable	Reduced		Trend	Stable	Reduced
Oesophageal cancer	135	123	113	100	39	41	38	33
Colon and rectum cancer	316	325	290	246	43	58	52	44
Liver cancer	153	236	216	188	40	75	68	59
Gallbladder and biliary tract cancer	34	61	56	49	< 5	-	-	-
Pancreatic cancer	62	99	88	75	21	28	25	21
Breast cancer	220	274	241	208	23	34	30	26
Uterine cancer	194	263	245	223	9	16	15	13
Ovarian cancer	20	19	17	15	< 5	10	9	7
Kidney cancer	147	257	234	203	19	33	30	26
Thyroid cancer	94	155	140	121	< 5	-	-	-
Non-Hodgkin's lymphoma	156	185	163	138	10	16	14	12
Multiple myeloma	100	149	131	112	9	18	16	13
Leukaemia (all types)[d]	156	237	212	181	16	27	23	20
Ischaemic heart disease	4,892	6,230	5,723	5,020	351	350	319	271
Ischaemic stroke	1,174	1,819	1,673	1,481	13	27	25	21
Haemorrhagic stroke	530	842	792	721	59	75	69	62
Hypertensive heart disease	19	37	35	32	21	45	42	38
Atrial fibrillation and flutter	1,976	3,381	3,093	2,703	35	73	65	54
Asthma	553	667	611	529	11	-	-	-
Gallbladder and biliary diseases	3,451	4,606	4,321	3,876	14	-	-	-
Alzheimer's disease and other dementias	359	625	558	466	154	336	297	244
Diabetes mellitus	2,569	5,163	4,930	4,539	132	101	95	85
Chronic kidney disease due to diabetes mellitus[e]	33,529	49,614	46,703	42,629	40	120	111	98

Linked disease	Attributable hospitalisations				Attributable deaths			
	2016	2026			2015[a]	2026 [b,c]		
		Trend	Stable	Reduced		Trend	Stable	Reduced
Chronic kidney disease due to glomerulonephritis[e]	14,572	21,685	20,510	18,637	< 5	-	-	-
Chronic kidney disease due to hypertension[e]	7,301	12,662	11,785	10,436	18	-	-	-
Chronic kidney disease due to other causes[e]	14,801	23,108	21,604	19,552	55	65	60	52
Osteoarthritis of the hip	535	899	798	680	N/A	-	-	-
Osteoarthritis of the knee	2,802	4,407	4,047	3,582	N/A	-	-	-
Gout	300	550	514	455	N/A	-	-	-
Low back pain	854	1,373	1,223	1,039	N/A	-	-	-
Cataract	3,228	7,036	6,243	5,312	N/A	-	-	-
Obesity	4,421	6,235	6,235	6,235	27	-	-	-
Total attributable to excess body mass	**99,651**	**153,321**	**143,547**	**129,782**	**1,174**	**1,550**	**1,404**	**1,198**
Total for linked diseases	262,351	-	-	-	5,854	-	-	-
Proportion of linked diseases attributable to excess body mass	38.0%	-	-	-	20.1%	-	-	-
Total for all diseases	1,069,412	-	-	-	14,514	-	-	-
Proportion of all diseases attributable to excess body mass	9.3%	-	-	-	8.1%	-	-	-

[a] There were no child deaths with a linked disease as a principal cause in 2015 and child deaths were not projected for 2026.

[b] No death projections are given where there were less than 20 deaths in historical data (10 years) for each sex.

[c] Projections based on less than 50 hospitalisations or deaths should be interpreted with caution.

[d] All leukaemia types grouped for projection calculations owing to small numbers.

[e] Includes admissions for dialysis.

Attributable hospitalisation costs 2016

In 2016, hospitalisations attributable to excess body mass in adults and children cost the WA health system an estimated $338.7 million or 6.1 per cent of the cost of all hospitalisations (**Table 5**). The most costly hospitalised conditions attributable to excess body mass were ischaemic heart disease ($52.7 million), obesity ($46.7 million), osteoarthritis of the knee ($46.2 million), gallbladder and biliary disease ($32.9 million), and diabetes mellitus ($22.5 million). These five conditions accounted for 59.4 per cent of hospital costs attributable to excess body mass. In addition, chronic kidney disease due to diabetes mellitus, glomerulonephritis, hypertension and other causes totalled $41.6 million, or 12% of hospitalisation costs attributable to excess body mass in 2016.

Females accounted for greater total hospitalisation costs attributable to excess body mass than males ($171.8 million and $166.9 million respectively) (**Figure 7**). Females incurred considerably greater costs at younger ages (up to 50 years) than males. For males and females, hospitalisation costs peaked in the 65–69 year age group (at $47.2 million).

Figure 7. Hospitalisation costs attributable to excess body mass by age and sex, 2016.

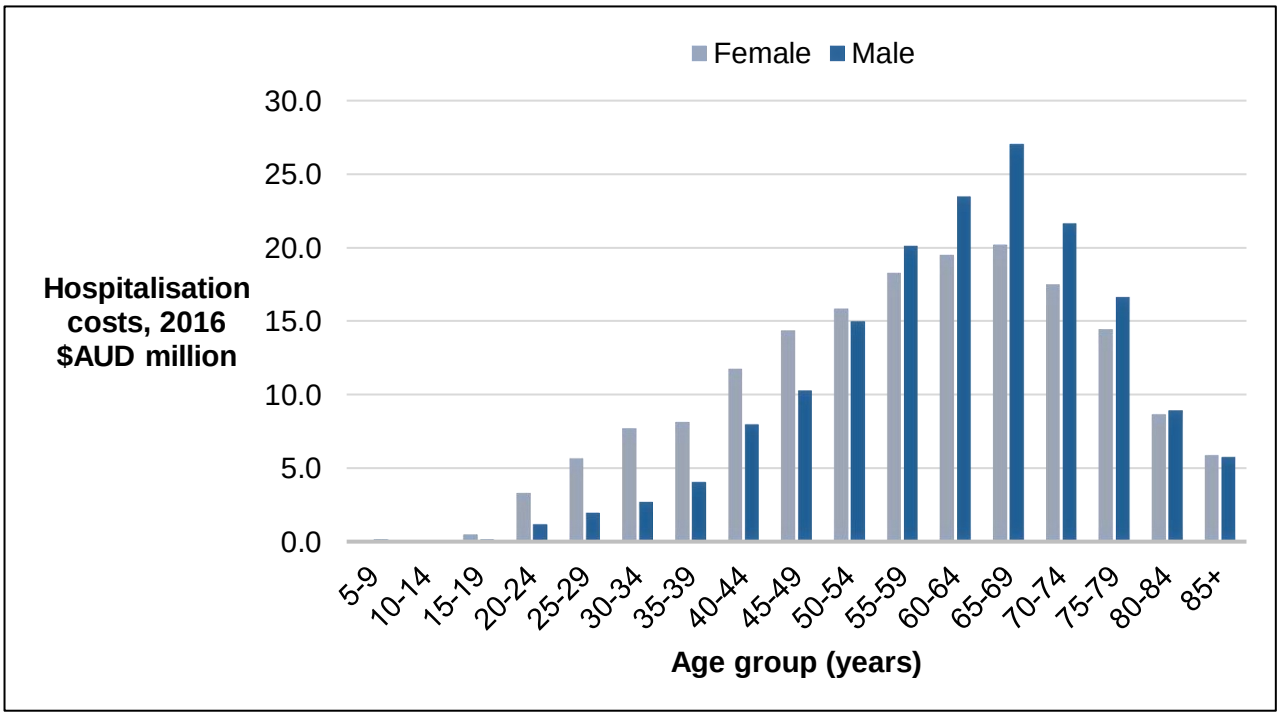


Table 5. Attributable hospitalisation costs in Australian dollars in 2016 and 2026 for adults and children under three scenarios.

Linked disease	2016	2026		
		Trend	Stable	Reduced
Oesophageal cancer	1,478,567	1,217,062	1,125,347	993,597
Colon and rectum cancer	5,724,961	6,484,950	5,786,534	4,915,730
Liver cancer	1,682,692	3,589,778	3,293,128	2,864,491
Gallbladder and biliary tract cancer	731,999	1,126,805	1,030,323	897,011
Pancreatic cancer	895,674	1,507,062	1,339,379	1,131,541
Breast cancer	2,252,044	3,085,825	2,717,996	2,344,342
Uterine cancer	2,028,987	3,358,150	3,133,285	2,856,684
Ovarian cancer	238,348	286,807	253,579	215,306
Kidney cancer	2,457,751	4,817,105	4,386,786	3,819,722
Thyroid cancer	1,011,544	1,936,260	1,753,625	1,515,730
Non-Hodgkin's lymphoma	1,979,906	2,584,135	2,284,889	1,931,995
Multiple myeloma	959,611	1,691,740	1,494,277	1,272,697
Leukaemia–all types [a]	2,307,525	4,245,824	3,793,014	3,234,298
Ischaemic heart disease	52,721,674	74,376,107	68,354,370	59,979,538
Ischaemic stroke	13,651,318	25,592,777	23,551,362	20,846,222
Haemorrhagic stroke	13,032,820	23,893,908	22,464,644	20,441,277
Hypertensive heart disease	273,578	363,355	342,920	310,901
Atrial fibrillation and flutter	10,034,820	21,327,462	19,514,765	17,060,784
Asthma	2,756,292	3,769,526	3,455,270	3,004,306
Gallbladder and biliary diseases	32,918,940	50,838,466	47,669,691	42,780,044
Alzheimer's disease and other dementias	4,583,241	9,730,354	8,683,836	7,263,568
Diabetes mellitus	22,486,665	57,435,408	54,842,494	50,510,524
Chronic kidney disease due to diabetes mellitus [b]	19,599,186	44,185,995	41,601,836	37,982,975
Chronic kidney disease due to glomerulonephritis [b]	8,699,945	18,705,811	17,694,861	16,081,194
Chronic kidney disease due to hypertension [b]	4,710,190	13,144,717	12,236,434	10,839,339
Chronic kidney disease due to other causes [b]	8,611,907	20,775,367	19,426,813	17,585,549

Linked disease	2016	2026		
		Trend	Stable	Reduced
Osteoarthritis of the hip	10,828,119	24,460,783	21,728,385	18,512,504
Osteoarthritis of the knee	46,253,345	61,254,623	56,262,497	49,806,742
Gout	1,744,936	3,621,524	3,388,543	2,999,264
Low back pain	6,321,408	10,611,284	9,456,395	8,036,624
Cataract	9,073,471	31,201,279	27,695,927	23,564,967
Obesity	46,684,842	78,903,841	78,903,841	78,903,841
Total hospitalisation costs attributable to excess body mass	**338,736,306**	**610,124,090**	**569,667,046**	**514,503,307**
Total hospitalisation costs for all linked diseases	1,150,607,430			
Proportion of costs for all linked diseases attributable to excess body mass	29.4%			
Total hospitalisation costs for all diseases	5,572,688,888			
Proportion of costs for all diseases attributable to excess body mass	6.1%			

[a] Leukaemia types grouped for projection calculations owing to small numbers.

[b] Includes admission costs for dialysis.

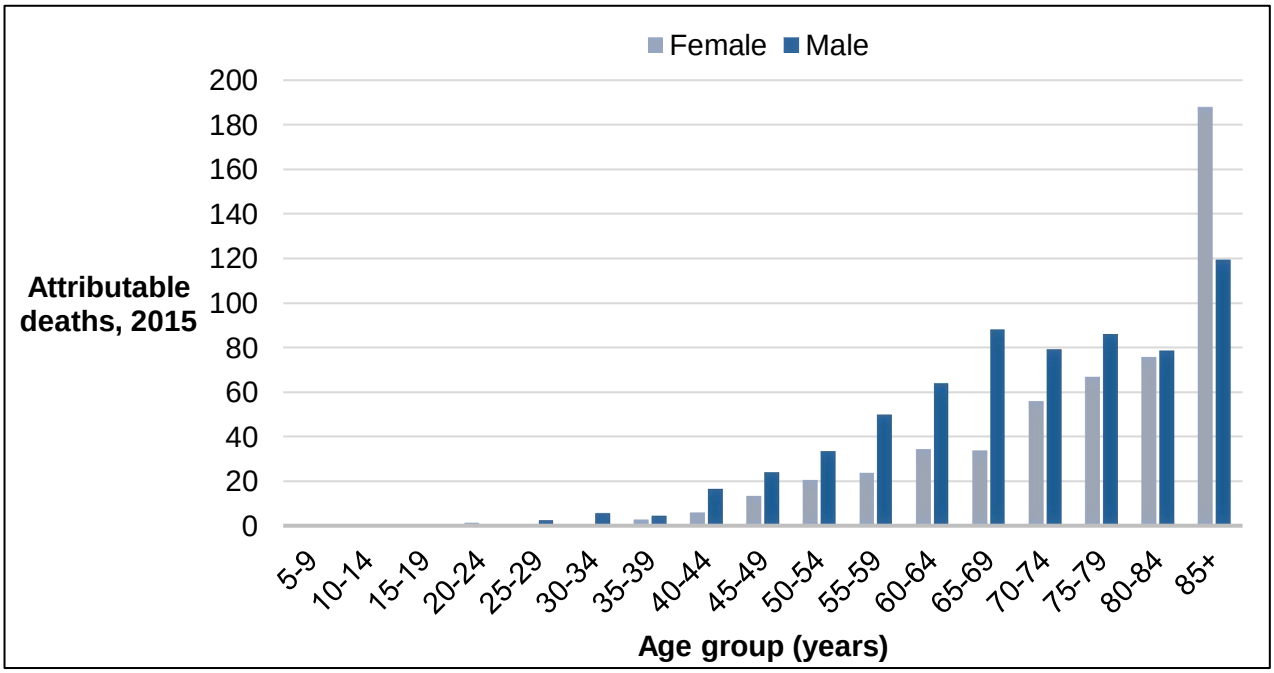
Attributable deaths 2015

In 2015, there were an estimated 1,174 deaths attributed to excess body mass, representing 20.1 per cent of all deaths from a linked disease and 8.1 per cent of all deaths in WA that year (**Table 4**). There were no child deaths due to a linked disease (obesity or asthma) in 2015.

The greatest number of adult deaths attributable to excess body mass were due to ischaemic heart disease (351 or 29.9%), Alzheimer's disease and other dementias (154 or 13.1%), diabetes mellitus (132 or 11.2%), and chronic kidney disease due to diabetes mellitus, hypertension, and other causes excluding glomerulonephritis (113 or 9.6%). Collectively, these linked diseases were responsible for 63.9 per cent of adult deaths attributable to excess body mass in 2015 (**Table 4**).

The number of adult deaths attributable to excess body mass in 2015 was greater for males (652) than females (522). **Figure 8** shows the distribution of deaths attributable to excess body mass according to age and sex (see also **Table B.2**). Although the age distribution of hospitalisations attributable to excess body mass is similar for males and females (**Figure 6**), more adult males die at a younger age from conditions attributable to excess body mass (**Figure 8**).

Figure 8. Adult deaths attributable to excess body mass by age and sex, 2015.



Projected burden due to excess body mass in 2026

Attributable hospitalisations in 2026

The WA population is predicted to be 3,273,950 persons in 2026, representing a 22 per cent increase on the 2016 population (2,676,780).[39] Owing to this population growth, natural increases in the total number of hospitalisations are expected.

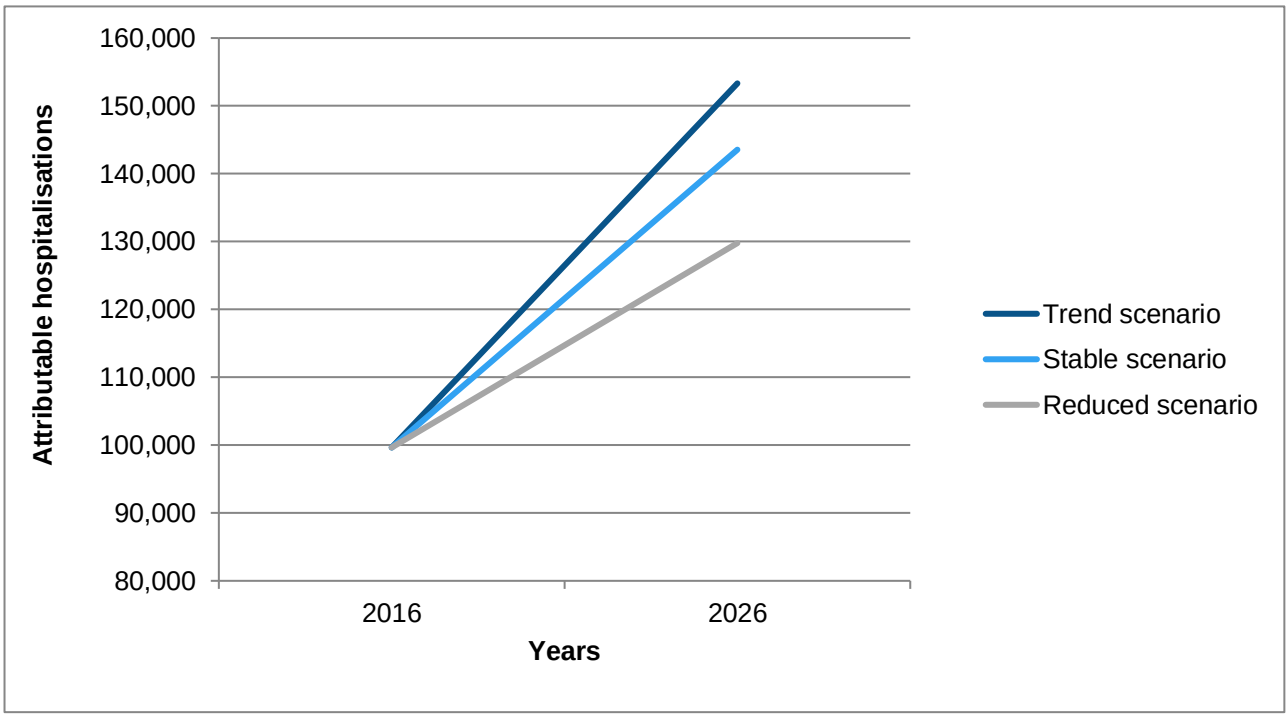
Under the trend scenario, if current WA trends in the population prevalence of excess body mass in adults (increasing) and children (stable) continue unchanged, the number of hospitalisations attributable to excess body mass is projected to increase by 54 per cent: from 99,651 in 2016 to 153,321 in 2026 (**Table 4**). Some of the largest increases in hospitalisations attributable to excess body mass between 2016 and 2026 are predicted to be due to cataract (118%) and diabetes mellitus (101%). Small declines are predicted in hospitalisations attributable to excess body mass linked with ovarian cancer and oesophageal cancer (noting that projections for ovarian cancer should be interpreted with caution owing to small numbers in 2016).

Under the stable scenario, if the WHO target of halting rises in obesity and overweight were met, hospitalisations attributed to excess body mass are predicted to increase to 143,547 in 2026 (**Table 4**). This represents a 44 per cent increase in hospitalisations compared with 2016 but 10 per cent (9,774) fewer hospitalisations compared with the trend scenario.

Under the reduced scenario, if all adults in the WA population with overweight or obesity in 2016 were to reduce their BMI by 1kg/m^2 from 2016 onwards, hospitalisations attributable to excess body mass are predicted to increase to 129,782 in 2026 (**Table 4**). This represents a 30 per cent increase in hospitalisations compared with 2016 but 24 per cent (23,539) fewer hospitalisations compared with the trend scenario.

Figure 9 illustrates the number of hospitalisations attributable to excess body mass predicted in 2026 for the trend, stable and reduced scenarios. **Table B.1** provides a breakdown for each scenario by sex and age group.

Figure 9. Hospitalisations attributable to excess body mass in 2016 and 2026 for adults and children under three scenarios.



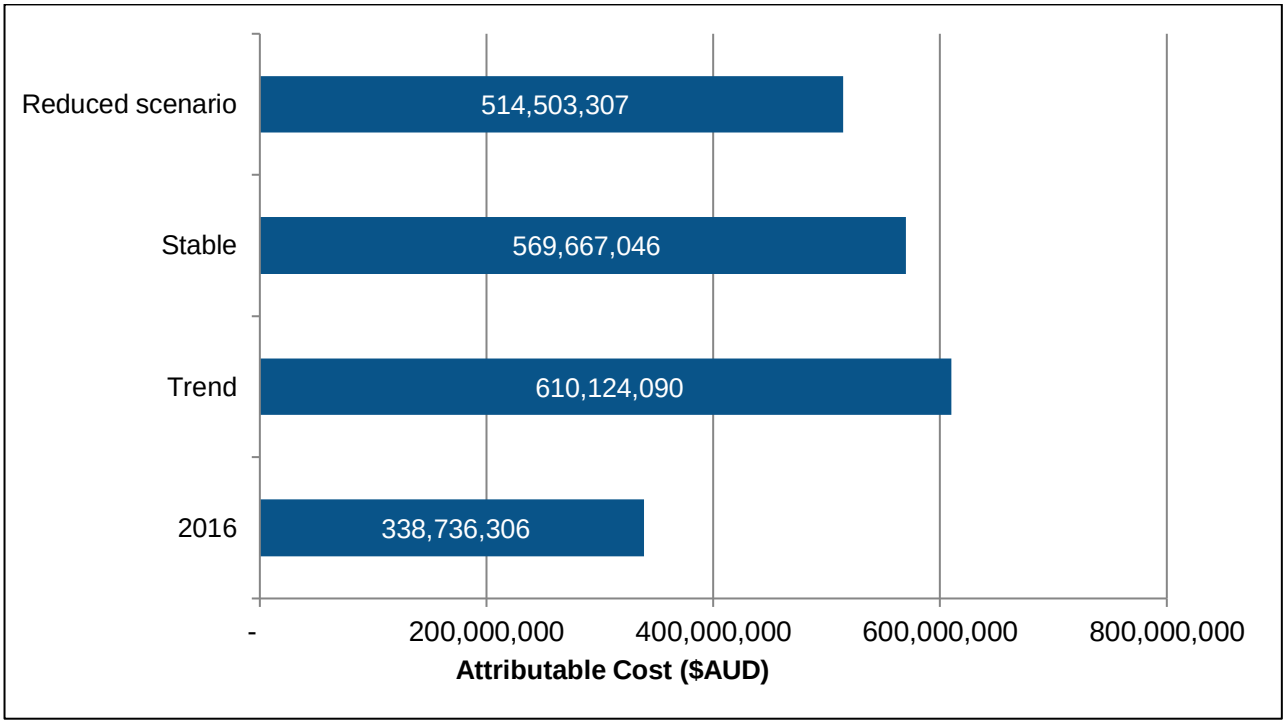
Projected attributable hospitalisation costs in 2026

Under the trend scenario, hospitalisation costs attributable to excess body mass are predicted to increase from $338.7 million in 2016 to $610.1 million in 2026 (**Table 5**). This represents an 80 per cent ($271.4 million) increase in costs to the WA health system over the next decade.

Under the stable scenario, hospitalisation costs attributable to excess body mass are predicted to increase to $569.7 million in 2026 (**Table 5**). This represents a 68 per cent increase in hospitalisation costs compared to 2016 but is 12 per cent ($40.5 million) less than hospitalisation costs predicted for the trend scenario.

Under the reduced scenario, hospitalisation costs attributable to excess body mass are predicted to increase to $514.5 million in 2026 (**Table 5**). This represents a 52 per cent increase in hospital costs compared to 2016, but is 28 per cent ($95.6 million) less than hospitalisation costs predicted for the trend scenario. **Figure 10** illustrates hospitalisation costs described above.

Figure 10. Estimated hospitalisation costs attributable to excess body mass in 2016 and 2026 for adults and children under three scenarios (2015/2016 AUD).



Under all three scenarios ischaemic heart disease, obesity, osteoarthritis of the knee, gall bladder and biliary diseases, and diabetes mellitus are expected to remain the top five most costly individual conditions attributable to excess body mass in 2026 (**Table 5**). However, the combined hospitalisation costs of chronic kidney disease due to diabetes mellitus, glomerulonephritis, hypertension, and other causes are predicted to grow to incur the greatest cost under all scenarios.

The predicted growth in costs due to hospitalisations attributable to excess body mass if current trends in overweight and obesity continue (trend scenario) by linked disease is shown in **Table 6**. Costs are predicted to grow by more than 100 per cent each due to hospitalisation for cataract, chronic kidney disease (all causes), diabetes mellitus, osteoarthritis of the hip, liver cancer, atrial fibrillation and flutter, Alzheimer's disease and other dementias, and gout. Obesity (as a principal diagnosis) along with chronic kidney disease (all causes combined) will overtake ischaemic heart disease to incur the greatest hospitalisation costs attributable to excess body mass in 2026.

Table 6. Hospitalisation costs attributable to excess body mass and ranking of linked diseases in 2016 and 2026 for adults and children (trend scenario).

#	2016	A$, 000	#	2026	A$, 000	Cost growth
1	Ischaemic heart disease	52,722	1	Obesity	78,904	69%
2	Obesity	46,685	2	Ischaemic heart disease	74,376	41%
3	Osteoarthritis of the knee	46,253	3	Osteoarthritis of the knee	61,255	32%
4	Gallbladder and biliary diseases	32,919	4	Diabetes mellitus	57,435	155%
5	Diabetes mellitus	22,487	5	Gallbladder and biliary diseases	50,838	54%
6	Chronic kidney disease due to diabetes mellitus	19,599	6	Chronic kidney disease due to diabetes mellitus [a]	44,186	125%
7	Ischaemic stroke	13,651	7	Cataract	31,201	244%
8	Haemorrhagic stroke	13,033	8	Ischaemic stroke	25,593	87%
9	Osteoarthritis of the hip	10,828	9	Osteoarthritis of the hip	24,461	126%
10	Atrial fibrillation and flutter	10,035	10	Haemorrhagic stroke	23,894	83%
11	Cataract	9,073	11	Atrial fibrillation and flutter	21,327	113%
12	Chronic kidney disease due to glomerulonephritis	8,700	12	Chronic kidney disease due to other causes [a]	20,775	141%
13	Chronic kidney disease due to other causes	8,612	13	Chronic kidney disease due to glomerulonephritis [a]	18,706	115%
14	Low back pain	6,321	14	Chronic kidney disease due to hypertension [a]	13,145	179%
15	Colon and rectum cancer	5,725	15	Low back pain	10,611	68%
16	Chronic kidney disease due to hypertension	4,710	16	Alzheimer's disease and other dementias	9,730	112%
17	Alzheimer's disease and other dementias	4,583	17	Colon and rectum cancer	6,485	13%
18	Asthma	2,756	18	Kidney cancer	4,817	96%
19	Kidney cancer	2,458	19	Leukaemia grouped (total)	4,246	84%
20	Leukaemia grouped (total)	2,308	20	Asthma	3,770	37%
21	Breast cancer	2,252	21	Gout	3,622	108%
22	Uterine cancer	2,029	22	Liver cancer	3,590	113%
23	Non-Hodgkin's lymphoma	1,980	23	Uterine cancer	3,358	66%
24	Gout	1,745	24	Breast cancer	3,086	37%
25	Liver cancer	1,683	25	Non-Hodgkin's lymphoma	2,584	31%
26	Oesophageal cancer	1,479	26	Thyroid cancer	1,936	91%
28	Thyroid cancer	1,012	28	Multiple myeloma	1,692	76%
29	Multiple myeloma	960	29	Pancreatic cancer	1,507	68%
30	Pancreatic cancer	896	30	Oesophageal cancer	1,217	-18%
31	Gallbladder and biliary tract cancer	732	31	Gallbladder and biliary tract cancer [b]	1,127	54%
33	Hypertensive heart disease	274	33	Hypertensive heart disease [b]	363	33%
36	Ovarian cancer	238	36	Ovarian cancer [b]	287	20%
	TOTAL	**338,736**		**TOTAL**	**610,124**	**80%**

[a] Costs due to chronic kidney disease (all causes) combined total $41.6 million in 2016 and $96.8 million in 2026 (133 per cent increase).
[b] Projection is based on fewer than 50 hospitalisations in 2016 and should be interpreted with caution

Projected attributable deaths in 2026

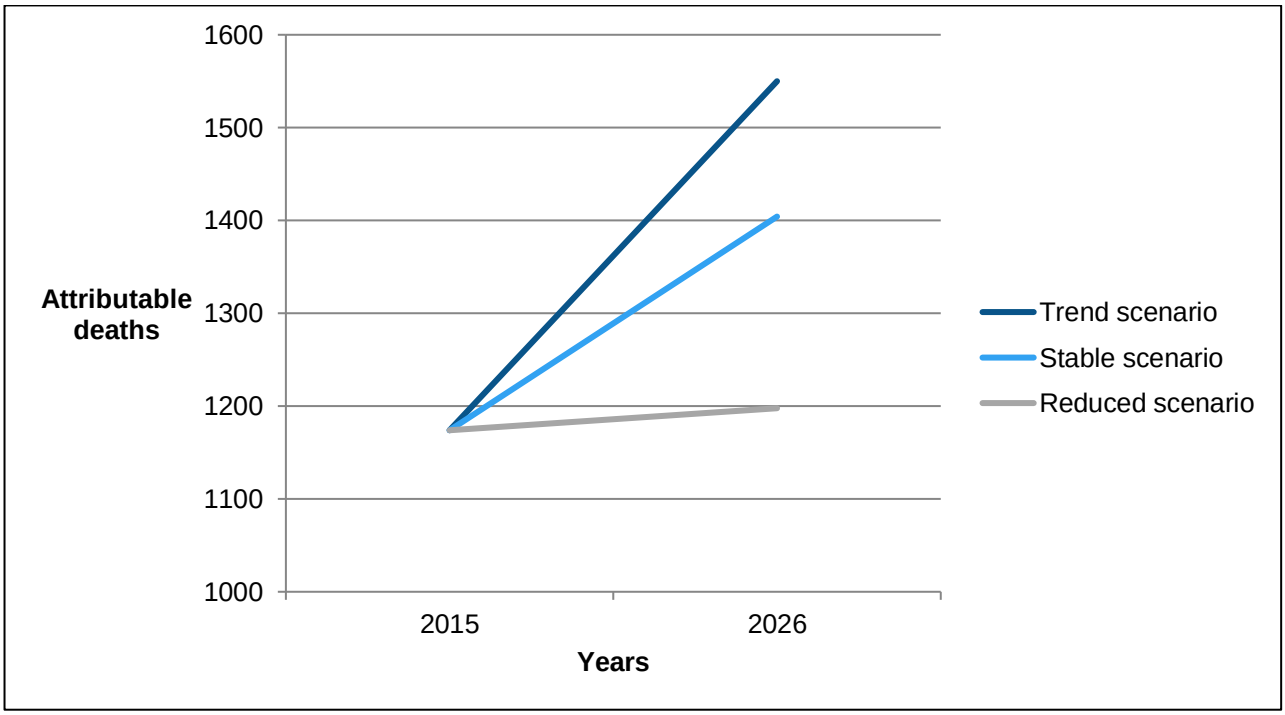
Under the trend scenario, the number of adult deaths attributable to excess body mass is estimated to increase from 1,174 in 2015 to 1,550 in 2026, or an additional 376 (32%) deaths (**Table 4**).

Under the stable scenario, adult deaths attributable to excess body mass are predicted to increase to 1,404 in 2026 (**Table 4**). This represents 230 (20%) more deaths compared to 2015, but 146 (12 per cent) fewer deaths compared with the trend scenario.

Under the reduced scenario, there would be a predicted 1,198 deaths in 2026 attributable to excess body mass (**Table 4**). This is 24 (2%) more deaths than in 2015, and 352 (30%) fewer deaths compared with the trend scenario.

Figure 11 illustrates attributable deaths described above. **Table B.3** in Appendix provides a breakdown for each scenario by sex and age group.

Figure 11. Adult deaths attributable to excess body mass in 2015 and 2026 under three scenarios.



If current trends in the prevalence of excess body mass continue, the greatest increases in adult deaths in 2026 attributable to excess body mass are predicted to be from: chronic kidney disease due to diabetes mellitus (200 per cent); ovarian cancer (183%); Alzheimer's disease and other dementias (118%); hypertensive heart disease (114%); and atrial fibrillation and flutter (108%) (**Table 4**). It should be noted however, that all of these projections, with the exception of Alzheimer's disease and other dementias, should be interpreted with caution as they are each based on fewer than 50 deaths in 2015.

Discussion

Summary of findings

This report describes the burden and cost of hospitalisations in WA in 2016 and mortality in 2015 attributable to excess body mass. The impacts of excess body mass in a decade's time (2026) are also predicted, based on the prevalence of overweight and obesity in WA increasing, decreasing, or remaining constant.

Key findings

- In 2016, 9.3 per cent of all hospitalisations for adults and children in WA were estimated to be attributable to excess body mass and cost the WA health system $338.7 million (2015/2016 AUD) or 6.1 per cent of all hospitalisation costs.
- In 2015, 8.1 per cent of all deaths in WA were estimated to be attributable to excess body mass. The majority (54%) of deaths attributable to excess body mass were due to ischaemic heart disease, Alzheimer's disease and other dementias, and diabetes mellitus.
- Males were more likely than females to be hospitalised and adult males more likely to die earlier (between 40 and 69 years of age) due to conditions linked with excess body mass. This corresponds with a higher prevalence of overweight and obesity across the adult male population and with the greatest gender disparity between the ages of 16 and 44 years.
- If current trends in child and adult overweight and obesity continue, the number of hospitalisations attributable to excess body mass in 2026 is predicted to increase by 54 per cent. The cost to the WA health system will rise by 80 per cent, to $610.1 million.
- If the WHO target of halting the rise in overweight and obesity were to be achieved in WA, there would be a cost saving of $40.5 million (12%) for associated hospitalisations in 2026 compared to costs if current trends in overweight and obesity continue.
- Applying a scenario whereby all adults with overweight or obesity in WA reduced their BMI by 1 kg/m^2 would translate to a cost saving of $95.6 million (or 28%) compared to current trends in excess body mass continuing. This scenario is an ambitious population health goal and a reduction in BMI greater than 1 kg/m^2 may be required for some individuals to achieve clinically significant health benefits[42] or to move from the overweight category (BMI 25+) into the healthy weight category (BMI 20-24.99). It would be insufficient to shift an individual from the obese category (BMI 30+) into the healthy weight category. However, these projections indicate that small shifts in population BMI can have a sizeable impact on costs, which concurs with the known health benefits of even modest amounts of weight loss if above a healthy weight.[42]
- The number of adult deaths attributable to excess body mass is projected to increase by 32 per cent in 2026 if current trends in overweight and obesity continue.
- Twelve per cent fewer adult deaths are predicted to occur if rises in overweight and obesity were to be halted.
- Thirty per cent fewer adult deaths are predicted if all adults who were overweight or obese in 2016 were to reduce their BMI by 1 kg/m^2.

Implications

A relatively small number of linked diseases were responsible for the bulk of hospital admissions attributable to excess body mass in WA. Just over 70 per cent of hospitalisations attributable to excess body mass in 2016 were for chronic kidney disease due to diabetes mellitus, glomerulonephritis, hypertension, and other causes. This is due to the frequency of visits required for renal dialysis. There is potential to reduce this burden on individuals and the health care system through obesity prevention programs and policies, and improved management of these conditions outside of the acute hospital system.

The linked diseases responsible for the greatest hospitalisation costs attributable to excess body mass in 2016 were (in decreasing order): ischaemic heart disease; obesity; osteoarthritis of the knee; chronic kidney diseases (all causes combined); gall bladder and biliary disease; and diabetes mellitus, totalling $242.7 million or 72 per cent of hospitalisation costs attributable to excess body mass in 2016. Projections indicate that the same conditions will be responsible for the bulk of hospitalisation costs attributable to excess body mass in 2026 under all scenarios. Assuming that current trends in overweight and obesity continue, cataract, chronic kidney disease (all causes), diabetes mellitus, osteoarthritis of the hip, liver cancer, atrial fibrillation and flutter, gout, and Alzheimer's disease and other dementias, are each predicted to incur more than 100 per cent growth in hospitalisation costs attributable to excess body mass between 2016 and 2026. Under all scenarios, obesity (as a principal diagnosis) and chronic kidney disease (all causes combined) will overtake ischaemic heart disease to incur the greatest hospitalisation costs attributable to excess body mass in 2026.

Areas for future focus

The projected burden and costs of excess body mass to the WA health system indicate a strong potential for return on investments in publicly funded obesity prevention and early intervention programs.

The Organisation for Economic Cooperation and Development (OECD) has presented an urgent economic case to scale up investments in policies to address obesity.[15] It estimated that excess body mass accounts for 8.6 per cent of Australia’s health expenditure and reduces Australia’s gross domestic product by 3.1 per cent.[15] Further, Australia ranks eighth highest out of 36 OECD countries for losses per capita per year in labour market outputs (A$1,788) due to excess body mass. The OECD has calculated that scaled up, national, population-wide interventions including menu and food labelling schemes, mass media campaigns, and regulation of the marketing of unhealthy products to children, could prevent 46,000 cases of chronic diseases such as type 2 diabetes and coronary heart disease, saving A$57 million per year in health costs.

In 2018, at the request of the Minister for Health, the Department of Health hosted the *WA Preventive Health Summit* to explore opportunities to reduce obesity and the harm caused by alcohol in WA. A common theme raised by experts and opinion leaders invited to the summit was that responsibility for obesity prevention does not sit solely in one agency. This was

illustrated by the range of policy domains identified for State Government action, some of which included:

- Taking a whole of government approach with long term commitments, to address the social determinants of excess body mass
- Removal of unhealthy food and drink promotions on State assets
- Introducing healthy food policies across WA Government Departments and agencies
- Amending planning regulations and processes to prioritise community health and wellbeing

The need to address overweight and obesity in WA has been further escalated in priority by the *WA Sustainable Health Review Final Report*[20] which recommended that government funding for prevention in WA increase to at least five per cent of total health expenditure by July 2029, with priority given to increased public health funding for obesity. The report also recommended targets to halt the rise in obesity in WA by July 2024 and to increase the proportion of the WA population with a healthy weight to the highest in any state or territory in Australia by July 2029.

Obesity prevention has been prioritised in successive *Western Australian Health Promotion Strategic Frameworks*, the first of which was developed in 2007.[43] The Department of Health currently invests in a number of population-wide obesity prevention programs, including the LiveLighter® healthy lifestyle promotion and education mass media campaign,[44, 45] the FoodSensations® adult food literacy program,[46] and the School Breakfast and Nutrition Education Program.[47]

Obesity has recently gained attention on the national health agenda. In late 2018, the Council of Australian Governments (COAG) Health Council agreed to a comprehensive national obesity strategy being developed by the middle of 2020.[48] One policy intervention that could be implemented by the Australian Government, is the introduction of a levy on the sugar content of sugar sweetened beverages (SSB).[49] This form of taxation has been effective at reducing the amount of sugar in SSB[50] and the consumption of SSB in several countries.[49]. Over 40 countries have implemented a form of taxation on SSB in order to reduce sugar consumption and the associated risk of overweight, and this number is continually increasing with the growing body of evidence demonstrating its effectiveness.[51]

In its *Global Action Plan for the Prevention and Control of Non-communicable Diseases 2013–2020,* the WHO called on all member states to halt rises in obesity in adults, children and adolescents.[41] The findings of the present report show that significant cost savings in hospitalisation costs can be made if the target of halting rises in obesity were to be achieved in the next decade.

Study limitations

This report provides robust estimates of direct inpatient admission costs only. Costs from emergency department presentations, pharmaceutical costs, or outpatient health care costs are not included. It is also important to note that costs estimated in this study represent a portion of total health system costs and do not include personal costs to individuals or costs to the community and economy, such as labour and productivity losses. The costs incurred in primary care and for allied and mental health services are not included. As such, the costs presented are conservative and underestimate the full cost of excess body mass.

Only those conditions attributable to excess body mass for which relative risks were available at the time of the study were considered. For example, the costs estimated in this study did not consider the burden from infertility, falls, sleep apnoea, or surgical complications associated with excess body mass. Only asthma and obesity could be analysed as linked diseases in children.

There is potential for the misclassification of excess body mass and measurement error in the population prevalence of overweight and obesity. Body mass index is a universally accepted method of determining overweight and obesity in populations.[13] However, different BMI ranges for overweight and obesity may be more appropriate for some ethnic groups e.g. South Asians and Aboriginal and Torres Strait Islander people.[42] The use of self-reported height and weight to calculate the population prevalence of overweight and obesity in WA is likely to lead to underestimations of the true prevalence and impact of excess body mass on hospital costs and mortality. However, an adjustment factor was applied to mitigate this.[33]

The reliability of cost of illness studies such as this is highly dependent on the list of linked diseases considered as well as having robust estimates of population exposures (overweight and obesity), costing data, and relative risks to calculate PAFs. The relative risks used in this study represent the relationship between excess body mass and the prevalence of health loss in a population from a linked disease, hospitalisations are used as a proxy for this, but they may not be directly comparable. Whether a patient is hospitalised or not depends on several factors other than disease progression, including age, sex, rurality, socioeconomic status and Aboriginal status.[52]

A further issue with cost of illness studies and the use of PAFs is the potential for double counting hospitalisations for the same health issue (linked disease) due to multi-morbidity.[21] To avoid inflated estimates, the present analysis focussed only on hospitalisations and deaths where a linked disease was the principal diagnosis or cause of death. Linked diseases as a secondary diagnosis (or comorbidity) were not included in impact estimates. For example, in the case of a patient hospitalised with a primary diagnosis of ischaemic heart disease and a secondary diagnosis of obesity, only the hospitalisation cost for ischaemic heart disease was counted. This potentially underestimates the true cost of hospitalisations attributable to excess body mass; however, an appropriate method is yet to be developed that can avoid double counting.

Study strengths

Despite these limitations, this study has advanced the methods applied in the earlier WA analysis[10] and extended internationally endorsed methodologies used in the *GBD* and *ABD Studies,* including updating the method to calculate TMRED, conducting subgroup analyses for linked disease groups, and including extended age groups for relative risks and categories of risk factor exposure (**Box 1**).

The present study uses an expanded list of linked diseases, reflecting an increasing number of conditions being recognised as attributable to excess body mass. In addition to linked diseases considered in earlier *GBD* and *ABD Studies*, the present study also treated obesity as a linked disease. The present study includes an expanded list of 36 linked diseases compared to 18 in the previous WA analysis by Scalley *et al.*[10] Furthermore, improvements in the evidence base on the causal relationships between excess body mass and updating of relative risks means that a more accurate estimation of disease burden could be made.

Finally, this study used the latest risk factor (excess body mass) prevalence data for WA and is the first to estimate the impact of excess body mass on hospitalisations in children in WA. In addition, it analyses excess body mass-related deaths in 2015.

Conclusions

Excess body mass is a significant contributor to hospitalisation costs and mortality in WA. If population levels of overweight and obesity continue to climb, it is projected that the cost to the WA health system will increase by 80 per cent in the decade between 2016 ($338.7 million) and 2026 ($610.1 million). This is an underestimate of the full costs of excess body mass to the WA health care system and to individuals, communities and the WA economy. By comparison, significant cost savings could be made if the population prevalence of overweight and obesity were to stabilise or decline.

The projected burden and costs of excess body mass indicate a strong potential for return on investments in publicly funded obesity prevention and early intervention programs, backed by robust policies and regulatory options to support Western Australians to achieve and maintain a healthy weight.

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Appendix A: Additional methods

Table A.1. Relative risks for excess body mass

Linked disease	Age groups	Burden type (morbidity/ mortality	BMI	Relative risk (LCI - UCI)		Source
				Males	Females	
Cancer						
Oesophageal cancer	20-85+	Both	Per 5kg/m^2	1.391 (1.077-1.754)	1.351 (1.012-1.745)	• Renehan AG, *et al*[53]
Colon and rectum cancer	20-85+	Both	Per 5kg/m^2	1.177 (1.145- 1.208)	1.059 (1.031-1.083)	• Karahalios A, *et al*.[54] • Renehan AG, *et al*[53] • Schlesinger S, *et al*[55]
Liver cancer	20-85+	Both	Per 5kg/m^2	1.289 (1.109-1.491)	1.176 (1.03-1.334)	• Chen Y, *et al*[56] • Renehan AG, *et al*[53] • Rui R, *et al*[57] • Tanaka K, *et al*[58] • Wang Y, *et al*[59]
Pancreatic cancer	20-85+	Both	Per 5kg/m^2	1.071(0.999-1.153)	1.092 (1.037-1.144)	• Alsamarrai A, *et al*[60] • Renehan AG, *et al*[53]
Gallbladder and biliary tract cancer	20-85+	Both	Per 5kg/m^2	1.155 (1.033-1.281)	1.344 (1.223-1.477)	• Park M, *et al*[61] • Renehan AG, *et al*[53]
Breast cancer (postmenopausal)	50-85+	Both	Per 5kg/m^2	-	1.089 (1.037-1.14)	• Renehan AG, *et al*[53] • Xia X, *et al*[62]
Uterine cancer	20-85+	Both	Per 5kg/m^2	-	1.613(1.543-1.681)	• Aune D, *et al*[63] • Jenabi E, Poorolajal J[64]
Ovarian cancer	20-85+	Both	Per 5kg/m^2	-	1.038 (0.999-1.077)	• Aune D, *et al*[63] • Collaborative Group on Epidemiological Studies of Ovarian Cancer[65] • Liu Z, *et al*[66] • Renehan AG, *et al*[53]
Kidney cancer	20-85+	Both	Per 5kg/m^2	1.24 (1.171-1.313)	1.32 (1.254-1.394)	• Renehan AG, *et al*[53] • Wang F, Xu Y[67]
Thyroid cancer	20-85+	Both	Per 5kg/m^2	1.221 (1.068-1.381)	1.136 (1.094-1.178)	• Ma J, *et al*[68] • Renehan AG, *et al*[53]

Linked disease	Age groups	Burden type (morbidity/ mortality	BMI	Relative risk (LCI - UCI)		Source
Non-Hodgkin's lymphoma	20-85+	Both	Per 5kg/m^2	1.089 (1.038-1.143)	1.068 (1.01-1.125)	• Larsson SC, Wolk A[69]
Multiple myeloma	20-85+	Both	Per 5kg/m^2	1.089 (1.027-1.153)		• Teras LR, *et al*[70]
Acute lymphoid leukaemia	20-85+	Both	Per 5kg/m^2	1.086 (1.053-1.119)	1.131 (1.061-1.208)	• Castillo JJ, *et al*[71] • Renehan AG, *et al*[53]
Chronic lymphoid leukaemia	20-85+	Both	Per 5kg/m^2	1.086 (1.053-1.119)	1.131 (1.061- 1.208)	• Castillo JJ, *et al*[71] • Renehan AG, *et al*[53]
Acute myeloid leukaemia	20-85+	Both	Per 5kg/m^2	1.086 (1.053-1.119)	1.131 (1.061-1.208)	• Castillo JJ, *et al*[71] • Renehan AG, *et al*[53]
Chronic myeloid leukaemia	20-85+	Both	Per 5kg/m^2	1.086 (1.053-1.119)	1.131(1.061-1.208)	• Castillo JJ, *et al*[71] • Renehan AG, *et al*[53]
Other leukaemia	20-85+	Both	Per 5kg/m^2	1.086 (1.053-1.119)	1.131(1.061-1.208)	• Castillo JJ, *et al*[71] • Renehan AG, *et al*[53]
Cardiovascular disease						
Ischaemic heart disease	20-85+	Both	Per 5kg/m^2	1.17 (1.091-1.252) to 2.274 (1.259-3.683)		• Singh GM, *et al*[72]
Ischaemic stroke	20-85+	Both	Per 5kg/m^2	1.068 (0.992-1.143) to 2.472 (1.4-3.975)		• Singh GM, *et al*[72]
Haemorrhagic stroke	20-85+	Both	Per 5kg/m^2	1.07 (0.928-1.219) to 3.066 (1.751- 5.334)		• Singh GM, *et al*[72]
Hypertensive heart disease	20-85+	Both	Per 5kg/m^2	1.697 (1.069-2.618) to 3.122 (1.588- 5.498)		• Singh GM, *et al*[72]
Atrial fibrillation and flutter	20-85+	Both	Per 5kg/m^2	1.344 (1.231-1.473)		• Wanahita N, *et al*[73]
Renal and endocrine disease						
Diabetes mellitus	20-85+	Both	Per 5kg/m^2	1.461 (1.207-1.758) to 3.547 (2.314-5.219)		• Singh GM, *et al*[72]
Chronic kidney disease due to diabetes mellitus	35-85+	Both	Per 5kg/m^2	1.431 (0.802-2.396) to 1.746 (1.054- 2.746)		• Emerging Risk Factors Collaboration, Wormser D, Kaptoge S, *et al*[74] • Ni Mhurchu C, *et al*[75] • Prospective Studies Collaboration, Whitlock G, Lewington S, *et al*[76]
Chronic kidney disease due to hypertension	35-85+	Both	Per 5kg/m^2	1.437 (0.829-2.415) to 1.763 (1.09 -2.755)		
Chronic kidney disease due to glomerulonephritis	35-85+	Both	Per 5kg/m^2	1.452 (0.851- 2.345) to 1.742 (1.021- 2.775)		
Chronic kidney disease due to other causes	35-85+	Both	Per 5kg/m^2	1.433 (0.778- 2.344) to 1.732 (1.052-2.681)		

Linked disease	Age groups	Burden type (morbidity/ mortality	BMI	Relative risk (LCI - UCI)		Source
Musculoskeletal disease						
Gout	20- 85+	Morbidity	Per 5kg/m^2	1.628 (1.34- 1.964)	1.493 (1.322-1.677)	• Aune D, *et al*[77]
Osteoarthritis of the hip	20- 85+	Morbidity	Per 5kg/m^2	1.11 (1.06-1.157)		• Jiang L, *et al*[78] • Jiang L, *et al*[79] • Silverwood V, *et al*[80]
Osteoarthritis of the knee	20-85+	Morbidity	Per 5kg/m^2	1.37 (1.201- 1.538)		
Low back pain	20-85+	Morbidity	Per 5kg/m^2	1.099 (1.075-1.123) - 1.101(1.076- 1.128)		• Shiri R, *et al*[81]
Other						
Cataract	20-85+	Morbidity		1.104 (1.051-1.156)		• Ye J, *et al*[82]
Asthma (adult)	20-85+	Both	Per 5kg/m^2	1.402 (1.275-1.532)		• Beuther DA, Sutherland ER[83]
Asthma (child)	5-19	Both	Obese	2.2 (1.51- 3.19)		• Mebrahtu TF, *et al*[84]
Asthma (child)	5-19	Both	Overweight	1.33 (1.11 -1.6)		
Gallbladder and biliary diseases	20- 85+	Both	Per 5kg/m^2	1.464 (1.291-1.64)	1.729 (1.571-1.893)	• Aune D, *et al*[63]
Alzheimer's disease and other dementias	65-85+	Both	Per 5kg/m^2	1.214 (1.047-1.404)		• Profenno LA, *et al*[85]

Source: *2016 Global Burden of Disease Study*[6]

Table A.2. ICD-10 and ICD-10-AM codes used for mortality and hospitalisations

Linked disease	ICD10 (mortality)[a]	ICD10-AM 9th edition (morbidity)[b]
Alzheimer's disease and other dementias	F00-F03.9, G30-G31.1, G31.8-G31.9	F00-F03.9, F05.1, G30-G31.1,G31.8-G31.9, U79.1
Asthma	J45-J46.9	J45-J46.9, U83.3
Atrial fibrillation and flutter	I48-I48.9	I48-I48.9
Breast cancer	C50-C50.9, D05-D05.9, D24-D24.9, D48.6, D49.3, N60-N60.9	C50-C50.9, Z85.3
Cataract	-	H25-H26.9, H28.1, H28.2
Chronic kidney disease- due to diabetes mellitus	E10.2, E11.2, E12.2, E13.2, E14.2	E09.21, E09.29, E10.2, E11.2,E13.2, E14.2
Chronic kidney disease- due to glomerulonephritis	N03-N06.9	N03-N06.9
Chronic kidney disease- due to hypertension	I12-I13.9	I12- I13.9
Chronic kidney disease- other causes	N02-N02.9, N07-N08.8, N15.0, Q61-Q62.8	N02-N02.9
Colon and rectum cancers	C18-C21.9, D01.0-D01.3, D12-D12.9, D37.3-D37.5	C18-C21.8, Z85.0
Diabetes mellitus	E10-E10.1, E10.3-E11.1, E11.3-E12.1, E12.3-E13.1, E13.3-E14.1, E14.3-E14.9, P70.0-P70.2, R73-R73.9	E09.3-E09.5, E09.7-E09.9, E10.0-E10.1, E10.3-E10.9, E11.0- E11.1, E11.3-E11.9, E13.0- E13.1, E13.3-E13.9, E14.0- E14.1, E14.3-E14.9
Gallbladder and biliary tract cancer	C23-C24.9, D13.5	C23-C24.9
Gallbladder and biliary disease	K80-K83.9	K80-K83.9
Gout	-	M10-M10.9, M10.3-M10.9
Haemorrhagic stroke	I60-I62.9, I67.0-I67.1, I68.1-I68.2, I69.0-I69.2	I60-I62.9, I67.0-167.1, I69.0-I69.2
Hypertensive heart disease	I11-I11.9	I11-I11.9
Ischaemic heart disease	I20-I25.9	I20-I25.9, U82.1
Ischaemic stroke	G45-G46.8, I63-I63.9, I65-I66.9, I67.2-I67.3, I67.5-I67.6, I69.3	G45-G46.8, I63-I63.9, I65- I66.9, 167.2-167.3, 167.5-I67.6, I69.3- I69.4
Kidney cancer	C64-C65.9, D30.0-D30.1, D41.0-D41.1	C64-C65.9, Z85.5
Leukaemia- all	C91-C95.9	C91-C95.9
Leukaemia- Acute Myeloblastic Leukaemia	C92.0, C92.3-C92.6, C93.0, C94.0, C94.2, C94.4-C94.5	C92.0, C92.3-C92.9, C93.0,
Leukaemia- Chronic Lymphocytic Leukaemia	C91.1	C91.1
Leukaemia- Chronic Myeloid Leukaemia	C92.1	C92.1, C92.2

Linked disease	ICD10 (mortality)[a]	ICD10-AM 9th edition (morbidity)[b]
Leukaemia- other	C91.2-C91.9, C92.2, C92.7-C92.9, C93.1-C93.9, C94.1, C94.3, C94.6-C95.9	C90.1, C91.3-C91.9
Liver cancer due to HBV, HCV, alcohol and other	C22-C22.9, D13.4	C22-C22.9
Low back pain	-	G54.4, M47.15-M47.18, M47.25-M47.28, M47.89, M48.05-M48.08, M48.16-M48.19, M48.25-M48.28, M48.35-M48.38, M48.45-M48.48, M48.55-M48.58, M49.85-M49.88, M51.0, M51.1, M53.3, M53.85, M53.88, M54.05, M54.09, M54.15- M54.18, M54.3-M54.5
Multiple myeloma	C88-C90.9	C90.0, C90.2, C90.3
Non-Hodgkin lymphoma	C82-C86.6, C96-C96.9	C82-C86.6, C96-C96.9
Obesity	E66.0, E66.2, E66.8, E66.9,	E66.0, E66.2, E66.8, E66.9, U78.1
Oesophageal cancer	C15-C15.9, D00.1, D13.0	C15-C15.9
Ovarian cancer	C56-C56.9, D27-D27.9, D39.1	C56-C57.9
Pancreatic cancer	C25-C25.9, D13.6-D13.7	C25-C25.4,C25.7-C25.9
Thyroid cancer	C73-C73.9, D09.3, D09.8, D34-D34.9, D44.0	C73-C73.9
Uterine cancer	C54-C54.9, D07.0-D07.2, N87-N87.9	C54-C54.9, C55, Z85.4

[a] **Source:** 2016 Global Burden of Disease Study[6]

[b] **Source:** 2016 Global burden of Disease Study[6] adapted to Australia with assistance from WA Clinical Coding Authority.

Appendix B: Additional tables

Table B.1. Attributable hospitalisations in 2016 and 2026 under various scenarios by sex and 5-year age groups.

Age group	2016	2026			Age group	2016	2026			Age group	2016	2026		
		Trend	Stable	Reduced			Trend	Stable	Reduced			Trend	Stable	Reduced
Males					Females					Combined				
5-9	37	51	46	36	5-9	28	39	32	26	5-9	65	90	78	62
10-14	16	12	13	10	10-14	12	9	12	10	10-14	28	20	24	19
15-19	16	20	20	19	15-19	50	66	62	60	15-19	66	86	81	79
20-24	111	125	125	113	20-24	355	492	479	442	20-24	466	617	604	555
25-29	183	223	215	196	25-29	597	736	733	709	25-29	780	960	947	905
30-34	296	388	363	343	30-34	806	971	960	916	30-34	1102	1,359	1,323	1,258
35-39	1,652	2,518	2,682	2,466	35-39	1,447	2,339	2,285	2,085	35-39	3,099	4,857	4,967	4,551
40-44	2,849	3,444	3,319	3,051	40-44	3,331	3,939	3,654	3,401	40-44	6,180	7,383	6,973	6,452
45-49	4,257	6,878	5,973	5,465	45-49	4,530	6,874	6,454	6,008	45-49	8,787	13,752	12,427	11,474
50-54	5,909	7,431	7,300	6,610	50-54	4,618	6,328	5,928	5,502	50-54	10527	13,758	13,229	12,111
55-59	5,541	5,482	5,299	4,814	55-59	5,654	8,041	7,434	6,814	55-59	11,195	13,523	12,733	11,629
60-64	6,373	9,697	9,067	8,449	60-64	7,533	10,677	10,239	9,636	60-64	13,906	20,374	19,921	18,086
65-69	8,296	11,833	10,891	9,887	65-69	6,645	9,044	9,031	8,417	65-69	14,941	20,877	18,487	18,304
70-74	6,311	10,380	10,071	8,966	70-74	4,888	9,656	8,416	7,569	70-74	11,199	20,036	18,487	16,536
75-79	5,139	10,357	9,740	8,470	75-79	3,724	7,160	6,479	5,786	75-79	8,863	17,517	16,218	14,256
80-84	3,083	6,247	5,565	4,737	80-84	2,177	4,056	3,495	2,999	80-84	5,260	10,303	9,060	7,736
85+	1,992	5,270	4,939	3,953	85+	1,193	2,540	2,228	1,816	85+	3,185	7,810	7,167	5,769
Total	52,061	80,356	75,627	67,585	Total	47,588	72,967	67,920	62,197	Total	99,649	153,322	143,547	129,782

Note: The numbers of hospitalisations presented may be affected by rounding error.

Table B.2. Attributable deaths in 2015 and 2026 under various scenarios by sex and 5 year age groups

Age group	2015	2026			Age group	2015	2026			Age group	2015	2026		
		Trend	Stable	Reduced			Trend	Stable	Reduced			Trend	Stable	Reduced
Males					Females					Combined				
5-9	0	0	0	0	5-9	0	0	0	0	5-9	0	0	0	0
10-14	0	0	0	0	10-14	0	0	0	0	10-14	0	0	0	0
15-19	0	0	0	0	15-19	0	0	0	0	15-19	0	0	0	0
20-24	0	<5	<5	<5	20-24	< 5	< 5	< 5	< 5	20-24	< 5	<5	<5	<5
25-29	< 5	<5	<5	<5	25-29	0	< 5	< 5	< 5	25-29	< 5	<5	<5	<5
30-34	5-10[a]	5	5	<5	30-34	<5	< 5	< 5	< 5	30-34	7	8	8	7
35-39	5-10[a]	9	9	9	35-39	< 5	< 5	< 5	< 5	35-39	8	12	12	11
40-44	17	12	11	10	40-44	6	8	7	6	40-44	23	19	18	17
45-49	24	27	23	21	45-49	13	12	11	10	45-49	37	39	34	31
50-54	34	32	31	28	50-54	21	16	15	14	50-54	55	48	46	42
55-59	50	52	50	44	55-59	24	31	29	26	55-59	74	83	78	70
60-64	64	76	70	64	60-64	34	35	33	30	60-64	98	111	103	94
65-69	88	94	83	73	65-69	34	42	42	38	65-69	122	136	126	111
70-74	79	93	90	79	70-74	56	69	59	52	70-74	135	162	149	131
75-79	86	128	119	102	75-79	67	93	82	72	75-79	153	221	201	174
80-84	79	96	85	71	80-84	76	118	100	85	80-84	155	215	185	156
85+	119	200	187	147	85+	188	285	247	199	85+	307	485	434	346
Total	652	829	768	655	Total	522	721	637	542	Total	1174	1550	1404	1198

[a] Values given as a range (5-10) to prevent back calculation of small number of deaths in other age groups using the total.

Note: The numbers of hospitalisations presented may be affected by rounding error.

Glossary

Attributable burden: The disease burden attributed to a particular risk factor. It is the reduction in burden that would have occurred if exposure to the risk factor had been avoided or had been reduced to its **theoretical minimum risk exposure distribution (TMRED).**

Attributable hospitalisations: the proportion of all hospitalisations with a principal diagnosis of a linked disease that can be attributed to excess body mass.

Attributable cost: the proportion of all hospitalisation costs for hospitalisations with a principal diagnosis of a linked disease that can be attributed to excess body mass.

Body mass index: An international index used to classify underweight, overweight and obesity. BMI is calculated by dividing a person's weight in kilograms by the square of their height in metres (kg/m^2).

Chronic disease: A disease that tends to be long lasting and persistent in its symptoms or development.

Comparative risk assessment: The process for estimating the burden of disease attributable to selected risk factors. It involves five key steps: selection of linked diseases, estimation of exposure distribution, estimation of effect sizes, choice of theoretical minimum risk exposure level, and calculation of attributable burden.

Disease: A disorder of structure or function in a human, animal, or plant, especially one that produces specific symptoms or that affects a specific location and is not simply a direct result of physical injury.

Disability-adjusted life years (DALY): Years of healthy life lost, either through premature death or, equivalently, through living with disability due to illness or injury.

Excess body mass: A term used to describe the amount of body mass a person has above what is considered ideal, including those who are overweight and obese. Defined as a BMI equal to or greater than 25 kg/m^2.

Hospitalisations: in this report hospitalisations refers to hospital separations (formal and statistical) from all private and public hospitals in WA. Emergency department presentations are excluded.

Linked disease: The disease or injury for which there is evidence that the probability of its occurrence is increased from risk factor exposure at harmful levels. **In this study the risk factor exposure under review is excess body mass.**

Obese: A category used to describe the amount of body mass a person has above what is considered ideal. Defined as a BMI equal to or greater than 30 kg/m^2.

Overweight: A category used to describe the amount of body mass a person has above what is considered ideal. Defined as a BMI equal to or greater than 25 kg/m^2, but less than 30 kg/m^2.

Population attributable fraction (PAF): For a particular risk factor and causally linked disease or injury, the percentage reduction in burden that would occur for a population if exposure to the risk factor were avoided or reduced to its theoretical minimum.

Relative risk: The risk of an event relative to exposure, calculated as the ratio of the probability of the event's occurring in the exposed group to the probability of it occurring in the non-exposed group. An RR of 1 implies no difference in risk; an RR <1 implies the event is less likely to occur in the exposed group; and an RR >1 implies the event is more likely to occur in the exposed group.

Theoretical minimum risk exposure distribution (TMRED): The risk factor exposure distribution that will lead to the lowest conceivable disease burden.

Years lived with disability (YLD): A measure of the years of what could have been a healthy life that were instead spent in states of less than full health. This is also referred to as non-fatal burden.

Years of life lost (YLL): A measure of the years of life lost due to premature mortality. This is also referred to as fatal burden.

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