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Obesity and injury in Australia: a review of the literature

Flinders University

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*Authoritative information and statistics
to promote better health and wellbeing*

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Contents

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Abbreviations

AAS	Active Australia Survey
ABS	Australian Bureau of Statistics
ACS	Australian Coding Standards
ACSM	American College of Sports Medicine
AIHW	Australian Institute of Health and Welfare
AusDiab	Australian Diabetes, Obesity and Lifestyle Study
BMI	Body mass index (weight in kilograms/ height in metres squared)
CDC	Centers for Disease Control and Prevention
DHAC	Commonwealth Department of Health and Aged Care
EHI	Exertional heat illnesses
FTE	Fulltime equivalent
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
ICD-10-AM	International Classification of Diseases, 10th Revision, Australian Modification
ICU	Intensive care unit
ISS	Injury Severity Scores
LOS	Length of stay
MOF	Multiple organ failure
MVC	Motor vehicle crash
NHDD	National Health Data Dictionary
NHF	National Heart Foundation
NHS	National Health Survey
NHMD	National Hospital Morbidity Database
OECD	Organisation for Economic Co-operation and Development
WHO	World Health Organization

Summary

Obesity and injury are major health burdens on society. Possible relationships between obesity and injury have recently been reported, but their nature and extent has been unclear. This report presents summary information from an overview of the existing literature to investigate obesity–injury relationships. It also surveys opportunities to fill relevant gaps in knowledge in Australia.

Does obesity alter risk of injury?

Findings are mixed but most evidence suggests that obesity increases the risk of injury.

Indications are that the probability of falls, trips or stumbles, and resulting musculoskeletal injury, rises with obesity. The increased risk of falls in the obese may be somewhat offset by the possible protective effects of fat mass as cushioning and of increased bone density in weight-bearing joints.

Sleep apnoea increases road injury risk and is strongly associated with obesity.

The interaction of obesity and injury risk in children is complex and evidence limited. Falls risk is higher for obese children, probably increasing rates of face, tooth and musculoskeletal injuries. Obesity is also a risk factor during pregnancy, with increased rates of injury to mother and baby.

Workers' obesity has been found to be associated with risk of workplace injury.

The rising prevalence of obesity is widely seen as a risk factor for nurses and workers in other occupations that require lifting people, though direct evidence of risk was not found.

The relationship of body mass and injury risk during sport is complicated by the diversity of sporting activities and by the fact that the usual BMI-based measure of obesity is not appropriate for many athletes, whose higher body mass index (BMI) can reflect increased muscle mass rather than fat.

Does obesity affect outcomes from injury?

Average length of stay in hospital is significantly longer for obese injured patients than their leaner counterparts. Greater requirements for respiratory support have also been shown for injured obese patients relative to the non-obese. Also, obese injured patients are more likely to suffer certain complications of care during the period in hospital following injury. Risk of death after serious injury appears to be raised by obesity, though findings are mixed in the most severely injured cases.

Filling information gaps in Australia

Findings of the literature review are mostly not specific to Australia and do not show the effect of obesity in association with injury on health burden or health service demand. The National Hospital Morbidity Database (NHMD), national surveys of health and other data sources have potential to be used to fill this gap.

1 Introduction

This report presents summary information from an overview of literature on relationships between injury and obesity. The report was written as an input to the planning of possible investigations into the topic and as background to policy.

What is obesity?

Obesity has been defined as ‘a physiological condition in which excess body fat has accumulated to an extent that can negatively affect health’ (Bruce-Keller et al. 2009). The measure used most commonly to describe the level of fatness in populations is the body mass index (BMI). BMI is a weight-for-height measure, introduced as the Quetelet Index in the 1830s and widely used for the past several decades to estimate population trends in fatness (Keys et al. 1972). BMI is calculated as weight (kg)/height (m)^2.

The BMI measurement is popular for epidemiological studies because of its simplicity and because it provides a fairly reliable indicator of the prevalence of obesity in populations (less so for obesity in individuals). However, there are limitations to its use, even in population studies. The relationship between BMI and obesity varies with body composition, height and some other factors. For example, BMI does not distinguish between weight associated with lean tissue, such as muscle and bone, and weight associated with fat. Athletes and sports participants commonly have larger muscle mass than other people with the same height and weight, and muscle mass influences BMI values.

Obesity can be measured more reliably in other ways, such as skinfold measurements, underwater weighing, bioelectrical impedance, and dual energy X-ray absorptiometry. However, these methods also have limitations related to difficulty of use in large populations and accuracy in specific populations.

There have been efforts to use BMI cut-offs to categorise people in terms of their risk for Type 2 diabetes and cardiovascular diseases (WHO 2004). This has led to the establishment of internationally recognised categories to monitor population trends in body size. A BMI value in the range of 18.5 kg/m^2 to less than 25 kg/m^2 is defined as normal weight, while obesity is defined as a BMI of 30 kg/m^2 or more (WHO 2000). The BMI range between normal and obese is defined as ‘overweight’. The WHO categories have been adopted as the national standard in Australia (National Health Data Committee 2003). The proportions of the population within these categories are monitored routinely and reported in national health publications.

Associations between BMI, percentage of body fat and body fat distribution have been shown to differ between ethnic groups and across age categories (WHO 2004). For example, some Asian populations have shown elevation of health risks at lower BMI points than Caucasians and current international guidelines recommend using a lower cut-off of 26 kg/m^2 as the threshold for obesity in Asian populations (WHO 2004).

It is difficult to measure the obesity of children accurately because of the physiological changes that occur with growth. Two childhood BMI methods have been developed, which take into account age and sex. The Cole method is widely used in Australia and Europe while the Centers for Disease Control and Prevention (CDC) methodology is used predominantly in the United States (CDC 2000; Cole et al. 2000). A detailed list of cut-offs can be obtained from the National Health Survey Users' Guide (ABS 2009b).

Trends in obesity

In Australia, and many other countries, the proportion of the population classified as overweight or obese has risen rapidly (WHO 2008). Australia is one of the few OECD countries where adult obesity prevalence is above 20% (OECD 2009). Among the OECD countries that estimate the prevalence of overweight and obesity by measuring samples of people, rather than by means of self-reported data, Australia ranks fourth highest for obesity, behind the United States, United Kingdom and New Zealand.

The prevalence of overweight or obesity is increasing in these countries for nearly all ages The increase in Australia has been one of the largest. It has been estimated that more than 2.6 million Australians (21% of the population) were obese (BMI > 30) in 1999–2000. This is more than double the proportion in 1980 (Cameron et al. 2003). More recent analysis, comparing measured data from the 1989–90, 2004–05 and 2007–08 National Health Surveys, show that the proportion of people aged 18 and over who were obese increased from 9% in 1989–90 to 19% in 2004–05 and to 25% in 2007–08. Men (26%) were more likely to be overweight or obese than women (24%) (ABS 2009a).

The prevalence of obesity among Australian children increased from 5% in 1995 to 7% in 2007–08. While there has been no change in the proportion of girls classified as obese (6%), there has been a significant increase in the proportion of boys who are obese, doubling from 4% in 1995 to 8% in 2007–08 (ABS 2009a). Since the 1950s, body fatness of Australian children aged 0–18, as determined from skinfold measurements, has increased at the rate of 6%–8% per decade (Norton et al. 2006).

Estimated cost of obesity

In 2008, the overall cost of obesity (not including overweight) to Australian society and governments was estimated to be $58.2 billion (Access Economics 2008), while the total direct financial cost of obesity for the Australian community was estimated to be $8.3 billion. The direct estimate includes productivity costs of $3.6 billion (44%), including short- and long-term employment effects, as well as direct financial costs to the Australian health system of $2 billion (24%) and carer costs of $1.9 billion (23%) (Access Economics 2008).

Injury in Australia

Injury is a major public health burden in Australia and throughout the world. In 2004, injury accounted for 17% of the global burden of disease for those aged 15–59 (WHO 2008). Apart from the substantial numbers of deaths related to injury worldwide, tens of millions of people require hospitalisation for non-fatal injury each year (WHO 2008). Most survived injuries heal, but increasing attention is being directed to the persisting burden due to some injuries, illustrated most starkly by spinal cord injury and severe traumatic brain injury (Cripps & Harrison 2008).

Almost half of all deaths in Australia for people aged between 1 and 44 are due to injury, and it causes the loss of more years of life than every major disease group except cancer and cardiovascular disease (AIHW 2010a).

Injury is diverse and the rates and types differ greatly among segments of the Australian population. Injury is the most common cause of mortality for children and young people aged 1 to 24 (AIHW 2010a). In 2007–08, injury and poisoning was the second leading cause of hospitalisations in children aged 0–14 (AIHW 2010a). Falls resulting in fractures and head injuries are the most common cause of admitted injury among older adults, accounting for more than 9% of total hospital bed-days occupied by people aged 65 and over in 2005–06 (Bradley & Pointer 2009).

Transport crashes, intentional self-harm and falls are the leading external cause of fatal and serious injury in Australia. Sex (male), age (children, young adults and old adults), place of residence (remote), Indigenous status (Aboriginal and Torres Strait Islander) and alcohol are all risk factors for injury (Bradley & Harrison 2008; Henley & Harrison 2009).

Why look at injury and obesity?

The trend toward increased obesity across age groups, for both males and females, makes it sensible to ask whether this will result in higher rates of injury and/or worse outcomes of injury in the population. As shown below, some aspects of injury risk and outcomes are influenced by obesity. An understanding of the effects of obesity on injury occurrence and consequences is necessary to enable this to be evaluated and managed.

Numerous studies have investigated the link between levels of BMI and the relative risk of mortality—either all causes or for specific causes of death. They have found a rising relative risk as BMI increases from the normal range to the overweight category (25 to 29.9 kg/m^2) to the obese category (> 30 kg/m^2) (Adams et al. 2006; Bogers et al. 2007; Gregg et al. 2005; Whitlock et al. 2009). However, most of these studies have focused on morbidity and mortality associated with cardiovascular and metabolic diseases or other chronic diseases. It is less clear if obesity has a similar detrimental impact on injury morbidity and mortality or whether there are some protective effects associated with obesity.

The relationship between obesity and injury is a relatively new area of study. Most papers on the topic date from the past decade. The early work tended to focus on obesity as a factor complicating severe trauma (e.g. Boulanger et al. 1992; Choban et al. 1991), influencing a safety-related behaviour (Lichtenstein et al. 1989) or as a risk factor for the occurrence of injury in a particular setting, such as sport (Van Mechelen et al. 1996).

More recently, Finkelstein and colleagues published the results of an investigation into obesity and injuries in US adults using data from a national representative survey (Finkelstein et al. 2007). The results showed a clear link between body mass index and the probability of injury. In a review of the literature, Morrison and Christoffel (2008) observed that obesity predisposed adults and children to different patterns of injury compared with their non-obese counterparts.

In 2008, the Office of the Australian Safety and Compensation Council released a paper exploring the implications of overweight and obesity for workplace health and safety and worker's compensation (OASCC 2008). The paper, among other things, identified increased workplace absenteeism, lower productivity and work limitations due to increased personal injuries suffered by obese people. This paper provides an example of institutional concern in Australia about obesity and injury.

This report surveys findings from these publications and other sources, particularly as they are relevant to injury prevention and responses to overweight and obesity in Australia. The final section provides an assessment of gaps in knowledge, particularly as they apply to Australia, and how these could be filled.

Scope of the literature review

The intent of this report is to summarise the existent literature on the relationship between obesity and injury. The review is limited to summarising the major findings and conclusions of the identified publications. No formal evaluation of the methodologies employed or the design of each of the studies was undertaken for this report. A comprehensive evaluation of the studies identified is beyond the scope of this report however we acknowledge the need for future investigations to more comprehensively assess the reliability and validity of the results of the studies identified and summarised here.

In the search for literature on the relationship between obesity and injury people of all age groups and both sexes were included. Medline, EMBASE and the Cochrane Database of Systematic Reviews were searched using terms relating to obesity, injury, outcomes and interventions. Searches were restricted to the titles of English language articles published between January 1990 and April 2010.

The following study designs were included:

- Interrupted time series studies, longitudinal studies, observational studies (cohort, case-control, cross-sectional) and randomised controlled trials.

The types of outcome measures covered in the review included:

- Change in injury rate, risk, severity or pattern.
- Change in prevalence of medical procedures, treatment modalities, length of stay (LOS), morbidity and mortality.

Overview of the report

Chapter 1 introduces the discussion of the obesity–injury relationship and identifies the scope of the literature review. Chapter 2 examines the literature on whether obesity alters the risk of injury and specific injury patterns are associated with obesity. Chapter 3 presents literature on whether obesity affects outcomes following injury. Chapter 4 examines the relationship between obesity and workplace injury. Chapter 5 reports on the associations between obesity, sport and physical activity, and injury. The report concludes with a discussion of what has been established in the literature to date and identifies specific gaps or areas that require further investigation. Sources of data to investigate the relationship between obesity and injury are described, as are projects capable of filling important gaps in knowledge in Australia.

2 Does obesity alter risk of injuries or the pattern of injuries sustained?

This chapter presents findings from the literature on the influence of obesity on the risk of sustaining an injury and the pattern of injuries.

Researchers in a variety of specialties from trauma and critical care medicine, occupational health and safety, to sport science have attempted to shed light on the question of injury risk and obesity. However, this is an emerging field and the findings vary regarding injury risk among individuals with obesity. Most researchers have identified an increased risk of unintentional injuries in obese persons (Bazelmans et al. 2004; Hu et al. 2009; Jones et al. 1993; Matter et al. 2007; Van Mechelen et al. 1996; Xiang et al. 2005). However, some have found no association between body size and injury risk (Wearing et al. 2006a) or even a reduced risk of certain injuries in elderly obese individuals (Wearing et al. 2006b).

Injury is diverse in terms of types of damage sustained (for example, fractures, sprains, lacerations), the mechanism or way it comes about (for example, fall, contact with a sharp object) and its circumstances of occurrence (for example, motor vehicle crash). Anyone can be injured, but certain groups in the population (such as the very young and the very old) tend to be injured in characteristic ways. The literature on injury and obesity summarised in this chapter reflects these areas of interest.

Falls

Obesity is an important factor related to falls, particularly (but not only) in the elderly. Obesity negatively affects balance and postural stability, increasing the risk of falling (Colne et al. 2008; Freidmann et al. 2001). Studies of the influence of obesity on postural stability in adults and among the elderly (de Rekeneire et al. 2003) have found that obesity is associated with impaired postural balance, even in relatively young individuals (Maffiuletti 2005; Teasdale et al. 2007). Fjelstad and colleagues (2008) found that obese adults had a higher prevalence of falling and ambulatory stumbling than their normal-weight counterparts. More than one-quarter of the obese subjects in their study reported a history of falling, whereas only 15% of the normal-weight group had a history of falling. Using mathematical modelling, Corbeil and colleagues (2001) have shown greater postural instability in obese subjects, suggesting that obese people were at an increased risk of falling and had a greater probability of stumbling compared with individuals who were not obese.

Paradoxically, obesity has been shown to be associated with a reduced risk of hip and wrist fractures in older adults (Wearing et al. 2006a, 2006b). The mechanism of the reduced fracture rate in obese adults is not fully understood, but may be attributable to greater bone density in weight-bearing joints as well as to a cushioning effect of fatness during falls (Anandacoomarasamy 2008).

In contrast, obesity has been associated with a greater risk of distal forearm and wrist fractures in children (Goulding et al. 2000a; Wearing et al. 2006a). This has been attributed to an increased risk of falling, compounded by decreased bone density in obese children, who are more likely than other children to be sedentary (Wearing et al. 2006b; Wilder & Cicchetti 2009).

Despite the protective effects of obesity on bone mineral density in adults (Pluijm et al. 2001), obesity is a predisposing factor for fractures caused by stumbling, tripping and low-energy falls and has been found to be a risk factor for elbow and ankle fractures requiring surgical treatment (Bostman 1994).

Road injuries

The higher prevalence of sleep-disordered breathing among obese people has been identified as a contributing factor to increased incidence of transport accidents in obese people (Fransen et al. 2002; Stoohs et al. 1994; Whitlock et al. 2003). In a cohort study of more than 10,500 New Zealand men and women, Whitlock and co-workers (2003) found that adults with a higher BMI were twice as likely as adults with BMI in the normal range to have a driver injury, after allowing for driving exposure. Mulgrew and colleagues found that obstructive sleep apnoea and obesity were associated with increased risk of driver involvement in crashes resulting in injury (Mulgrew et al. 2008).

In a systematic review of obstructive sleep apnoea and risk of motor vehicle crash, Tregear and colleagues found four studies that met their inclusion criteria and provided evidence on the role of obesity (Tregear et al. 2009). All four studies reporting on BMI and crash risk found that higher BMI was a risk factor for a motor vehicle crash in individuals with obstructive sleep apnoea (for which obesity is the strongest risk factor).

Musculoskeletal injuries

Researchers have found a positive correlation between the level of obesity and musculoskeletal injuries (AIHW 2010b; Finkelstein et al. 2007; Hu et al. 2009; Kortt & Baldry 2002; Mehotra et al. 2004). Injuries typically associated with obesity are disorders of the lower extremities (Coggon et al. 2000; Cooper et al. 1998; Felson et al. 1997; Lievense et al. 2002; Manek et al. 2003; Peltonen et al. 2003), lower back (Fransen et al. 2002; Hagen et al. 2002; Ostbye et al. 2007), wrists (Fjeldstad et al. 2008; Geoghegan et al. 2004; Oliveria et al. 1999) and shoulder (Miranda et al. 2001). Musculoskeletal conditions that required hospitalisation, including sprains, strains and dislocations, were also more common among obese individuals (Finkelstein et al. 2007; Matter et al. 2007).

Studies of lower extremity injuries have reported conflicting results regarding the relationship between BMI and the incidence of injuries. Some studies have demonstrated an increased incidence in individuals who are taller (Watson 1999) and heavier (Milgrom et al. 1991), while others reported no difference in the incidence of ankle sprain injury (Beynnon et al. 2001; Faude et al. 2006).

In a longitudinal cohort study of US military cadets undertaking regular sport and physical training, male cadets with ankle injuries had a significantly higher BMI than uninjured cadets (Waterman et al. 2010). Waterman et al. attributed to the higher mass moment of inertia acting about the ankle.

Studies have reported an increased incidence of lower extremity injuries (Gomez et al. 1998) and ankle sprain (Tyler et al. 2006) in high school football players with an above-average BMI. Gomez and colleagues reported that linemen in high school gridiron (American football) with a higher BMI were at a greater risk of lower extremity injury than those with lower BMI, with ankle sprain being the most common injury. Tyler et al. showed that male high school athletes with a higher BMI (> 95th percentile) had a fourfold higher incidence of ankle sprain than normal-weight male athletes, although the same has not been observed in female athletes (McHugh et al. 2006).

Overuse syndromes and osteoarthritis

Overuse conditions and certain other conditions of gradual onset and typically chronic duration are often, though not always, referred to as injuries, and practice varies on whether they are included in studies of injury (Cryer & Langley 2008). These types of conditions are often included with acute trauma in the fields of sports injury and occupational injury (ASCC 2007; Walden et al. 2005). They have been included in this review.

Elevated BMI has been associated with overuse syndromes (for example, plantar fasciitis, carpal tunnel syndrome), work-related injury and osteoarthritis. Obesity is one of the predominant risk factors for osteoarthritis in weight-bearing joints such as the knee and hip (AIHW 2010b; Mehotra et al. 2004). There appears to be a dose-response relationship between an increase in BMI and the incidence of arthritis (43.5% for obese compared with 27% for lean weight) as well as the need for surgical treatment of arthritic pathologies (Mehotra et al. 2004; Peltonen et al. 2003).

Obesity has also been associated with increased workplace injury, and obese workers typically report a greater incidence of work-restricting pain in the neck, back and lower extremities (Peltonen et al. 2003)—see Chapter 4 for more on this topic.

Childhood injuries

Obese children, in general, are at an increased risk of injury and greater morbidity (Bazelmans et al. 2004; Brown et al. 2006a; Leet et al. 2005; Timm et al. 2005). As with the literature concerning adults, research on the associations between obesity and injury in children is a new and evolving field.

A retrospective review of trauma patients admitted to a paediatric hospital in the United States found that obese children had an increased incidence of extremity fractures requiring surgical intervention and a lower incidence of head and abdominal injuries (BMI $\geq$ 95th percentile) (Rana et al. 2009). In a cross-sectional study of 938 6 to 11-year-old school children in Rome, Petti and co-workers (1997) showed that obese children were significantly more prone to dental trauma than non-obese children, a finding consistent with that of other researchers (Granville-Garcia et al. 2006; Nicolau et al. 2001; Soriano et al. 2007).

In a case-control study of 180 children admitted to an emergency department with an acute ankle injury, Zonfrillo and colleagues (2008) found a significant association between overweight children and presence of ankle injuries. In the baseline survey for a longitudinal cohort study of 13– to 14-year-old schoolchildren, Alexander and colleagues (1995) found that girls with a high BMI reported 5 times more injuries in the previous year than normal-weight girls, although they found no significant elevation of injury rates for boys with a high BMI.

A cross-sectional study of a representative population sample of 2,363 children aged 9 to 17 in Belgium showed that obesity increased the incidence of injuries requiring treatment in children, although there was no association between obesity and injuries that required hospitalisation (Bazelmans et al. 2004).

Timm and co-workers (2005) found that overweight and obese children with acute ankle injuries were more likely than others to report persistent symptoms of pain, weakness and recurrent ankle injury up to 6 months after an acute ankle sprain.

The studies reported here chiefly describe effects of obesity in childhood on injury in childhood. Childhood obesity has significant associations with cardiovascular and metabolic diseases in adulthood (Freedman et al. 1999; Maffeis & Tato 2001; Owen et al. 2009). It has yet to be shown whether obesity in childhood affects injury risk later in life. In a review of musculoskeletal development in obese children, evidence was found of structural and functional changes in musculoskeletal physiology as a consequence of obesity (Wearing et al. 2006a). This, the authors concluded, could contribute to the development of musculoskeletal disorders across the lifespan.

Pregnancy and birth associated injuries

Maternal obesity in pregnancy is associated with an increased risk of serious adverse outcomes, including injury, for both the mother and baby. These include an increased risk of dysfunctional labour (Bhattacharya et al. 2007), shoulder dystocia (Cedergren 2004) and emergency Caesarean section (Chu et al. 2007; Nuthalapaty et al. 2004; Sebire et al. 2001). There is also an increased risk of genital tract trauma and primary postpartum haemorrhage (Chu et al. 2007; Cnattingius et al. 1998; Kabiru & Raynor 2004; Sebire et al. 2001).

A meta-analysis of 33 cohort studies shows that the risk of Caesarean delivery was about 1.5 times higher for overweight women than those of normal weight, about 2 times higher for obese women and nearly 3 times higher for severely obese women (Chu et al. 2007). These elevations of risk were statistically significant.

Albers and colleagues (2006) analysed fetal and maternal outcomes in 1,164 pregnant women according to BMI. They found obese women had elevated rates of babies weighing > 4,000 grams at birth (fetal macrosomia) and genital tract trauma with vaginal birth. Fetal macrosomia is a key factor in the aetiology of spontaneous lacerations with normal vaginal birth (Albers et al. 2005). Likewise, increased surgical interventions such as vaginal extractions and episiotomy are also known to be associated with increased trauma and these have also been shown to increase with maternal BMI (Spellacy et al. 1985; Wax 2009).

Patterns of injuries

The different circumstances in which injuries occur tend to be associated with the occurrence of different types and severities of injury. For example, a typical pattern of injury for a passenger in a high-speed motor vehicle crash (MVC) may involve chest and abdominal injury from contact with a seatbelt during the crash, and head and limb injuries from contact with the interior of the car. The presence of obesity might alter the patterns.

Researchers have found different injury patterns in obese patients compared with lean patients (Arbabi et al. 2003; Boulanger et al. 1992; Brown et al. 2005; Maheshwari et al. 2009; Tagliaferri et al. 2009), often finding fewer head injuries and higher rates of chest and extremity injuries among obese patients. It has been argued that there may be a protective effect of abdominal fatness, reflected in a lower risk of abdominal injuries in overweight adults (Boulanger et al. 1992; Brown et al. 2005; Brown et al. 2006b) and overweight children (Brown et al. 2006a; Rana et al. 2009) in MVCs. Others, however, have found no difference in injury severity or injury pattern between obese and non-obese patients (Byrnes et al. 2005; Ciesla et al. 2006).

Some researchers have found more severe injuries, evidenced by higher injury severity scores (ISS), in obese trauma patients (Haricharan et al. 2009). Newell and colleagues (2007) found that ISS values were higher, to a statistically significant extent, among obese patients admitted during a 4-year period to a Level I trauma centre (ISS 24 $\pm$ 8 in normal weight patients vs 26 $\pm$ 10 in obese patients). Maheshwari and colleagues (2009) reviewed the fractures sustained in MVCs by patients at eight trauma centres in the United States and found that obese patients were significantly more likely than others to have severe types of distal femur fractures, though statistically significant differences in length of stay and other measures were not found. Likewise, Spaine & Bollen (1996) found more severe ankle fractures among obese patients who slipped, tripped or fell on the same level than non-obese patients.

In an early retrospective review of anthropometric profiles and injury patterns following blunt trauma, obese patients were found to have an increased risk of chest injuries and fractures of the pelvis and limbs but were less likely to have head injuries (Boulanger et al. 1992). In a review of 1,153 blunt trauma patients, Brown and colleagues (2005) found that obese adults had a higher frequency of chest injuries and limb fractures, but a lower frequency of head injuries. However, they did not find any relationship between BMI and injury severity. Others have shown an increased risk of head injuries, higher brain injury severity and higher mortality among obese vehicle occupants involved in MVCs reported to the Crash Worthiness Data System (Tagliaferri et al. 2009).

In a 3-year retrospective review of paediatric emergency department admissions, obese children were significantly less likely to sustain head and facial injuries than non-obese children but more likely to have thoracic and lower limb injuries (Pomerantz et al. 2010). Interestingly, active obese children presenting with lower limb injuries were more likely to sustain sprains than fractures. The researchers suggested that while the greater biomechanical forces on the lower limb may have resulted in the injury, those same forces may have led to greater bone density and therefore been protective against fractures.

Others have shown that obese youth are at risk for specific injuries such as upper and lower extremity fractures, and musculoskeletal injuries to the ankle (Goulding 2007; Wearing et al. 2006a; Zonfrillo et al. 2008). While this may seem at odds with the findings of Pomerantz et al., research has shown that sedentary obese children have lower bone density than either their normal-weight or physically active obese peers (Goulding et al. 2000b).

Matter and colleagues (2007) reviewed hospital separations data from the 2002 Nationwide Inpatient Sample in the United States. Among people hospitalised for treatment of an injury, differences were found between obese and normal-weight people in the pattern of injury. Musculoskeletal conditions such as sprains, strains, and dislocations; falls; injury due to overexertion, and self-inflicted poisoning were all more common among obese, compared with non-obese, patients.

An important weakness of the study by Matter et al. is that obesity status was based on the presence of ICD-9-CM codes for obesity and morbid obesity in discharge records, and not on height and weight measures. In a study of obesity among hospitalised children, ICD-9-CM codes for obesity (using a slightly broader set than that used by Matter and colleagues) were present in only 5.5% of the cases that met a definition of obesity based on height and weight recorded in patient files (Woo et al. 2009).

3 Does obesity affect outcomes following injury?

This chapter presents a summary of published evidence on how survival and certain other aspects of injury outcome are affected by obesity of the injured person. Epidemiological data suggests that obese patients suffer more complications and higher mortality than lean patients after injury, although evidence is mixed and differs between types of injury (for example, blunt or penetrating trauma) and types of consequence (for example, survival, or duration of stay in hospital).

Mortality

Obesity has been linked with increased mortality following traumatic injury (Arbabi et al. 2003; Brown et al. 2005; Byrnes et al. 2005; Choban et al. 1991; Neville et al. 2004). In a 12-month study of blunt trauma patients admitted to a surgical intensive care unit (ICU), Neville and colleagues (2004) found obese patients with a BMI > 30 were more than 5 times more likely to die from their injury than non-obese patients. Byrnes and co-workers (2005) found obese patients (BMI $\geq$ 35) to be nearly 3 times more likely to die after being injured than patients with a BMI < 35. Similarly, in a review of the US National Crashworthiness Data System, Zhu and colleagues (2006) found that obese males had a significantly increased risk of death due to MVCs. Interestingly, they did not find an increased risk of death for obese females. Others have also observed increased mortality in obese patients (Arbabi et al. 2003; Byrnes et al. 2005; Choban et al. 1991). Head injury has been the most common cause of death in the studies that show a link between obesity, trauma and mortality (Neville et al. 2004).

Other studies, however, suggest a lower-than-expected mortality in critically injured patients who are obese. In several studies, the survival of obese and non-obese groups after blunt trauma were not significantly different (Alban et al. 2006; Ciesla et al. 2006; Diaz et al. 2009; Duane et al. 2006; Newell et al. 2007; Tremblay & Bandi 2003). In a prospective study of seriously injured trauma patients (ISS > 15), Ciesla and colleagues (2006) found no relationship between obesity and mortality after adjusting for age, injury severity, blood transfusion during resuscitation, and development of post injury multiple organ failure (which substantially increases mortality in critically ill patients), although they excluded patients with isolated head injury and those who died within 48 hours of injury.

A review of 10 years of data from the National Burns Registry in the United States found that obese adults were more than twice as likely to die as non-obese patients (Thombs 2008).

Morbidity

Obese patients have a higher prevalence of cardiac, respiratory and metabolic co-morbidities that can impair their response to injury and result in post-injury complications (O'Brien et al. 2006; Sifri et al. 2008). Obese patients are also likely to require more medical resources as admitted patients and outpatients (Bertakis & Azari 2005).

Length of stay

Length of stay (LOS) generally refers to the duration of a single episode of hospitalisation and is calculated by subtracting the day of admission from the day of discharge. It can also be used in reference to the duration in a specialist care unit (for example ICU LOS).

Obese trauma patients have been found to have increased length of stay in hospital and in intensive care units (ICU) (Byrnes et al. 2005; Ciesla et al. 2006; Newell et al. 2007). Obese patients with traumatic brain injury required longer ICU stays (14 vs 11 days), and stayed in the hospital on average 7 days longer (27 days versus 20 days) (Brown et al. 2006b). In a prospective study of 716 trauma patients in Colorado, Ciesla and colleagues (2006) documented an increased LOS for obese patients in both ICU (21.3 ± 1.4 days vs 16.1 ± 0.6 days) and hospital (25.2 ± 1.1 vs 20.1 ± 1.6 days). Likewise, others have shown significant increases in both ICU and hospital LOS for obese injured patients (Byrnes et al. 2005; Newell et al. 2007). Severely injured obese children had a significantly longer ICU stay and higher risk of complications such as sepsis and wound infections (Brown et al. 2006a). In obese trauma patients requiring surgery, duration of hospitalisation, ICU length of stay and duration of ventilation were all significantly longer than for normal weight patients (Haricharan et al. 2009).

Obese patients were found to be more likely than normal-weight patients to remain in acute-care facilities for rehabilitation, instead of being discharged home or referred to a rehabilitation facility (Ciesla et al. 2006).

Less is known about the impact of obesity on LOS for patients with burns. Thombs (2008) found no difference in the length of stay of obese adults with burns compared with non-obese patients. However, the median length of stay was significantly longer for obese children with burns than non-obese children (9.3 vs 7.1 days) (Patel et al. 2010).

Ventilatory support

Severely injured patients sometimes require mechanical assistance to breathe (ventilatory support). Obesity is a pre-existing risk factor for pulmonary complications, and obese patients are considered technically more difficult to assist because their facial and neck anatomy make it more difficult to insert breathing tubes. In addition, they have altered respiratory mechanics which can hinder their oxygenation and pre-dispose them to respiratory failure following pulmonary or systemic injury (Kress et al. 1999; Sifri et al. 2008).

Obese trauma patients tend to require ventilatory support for longer than non-obese patients (Bochicchio et al. 2006; Chesser et al. 2010; Reiff et al. 2007; Sifri et al. 2008). For example, Newell and co-workers (2007) found that the extra period of ventilatory support averaged 3.1 days for obese patients and 4.9 days for morbidly obese patients. Similarly, Neville (2004) found that obese trauma patients were more likely to require respiratory support and were ventilated for longer (9.8 days vs 7.2 days).

Obese patients with traumatic brain injury required significantly more days of mechanical ventilation than non-obese patients (10 days versus 6 days) (Brown et al. 2006b). In obese patients requiring surgery after trauma, there was a significantly longer duration of mechanical ventilation (23.0 vs 13.6 days) (Haricharan et al. 2009). Likewise, in patients with chest trauma, obesity was associated with a longer duration of mechanical ventilation (Reiff et al. 2007).

Two studies, however, have shown that rates of respiratory complications and requirement for ventilatory support did not differ between obese and non-obese patients following injury when adjustments were made for severity of injury and age (Dossett et al. 2008; Peake et al. 2006).

Effect of obesity on progression of injury cases

A growing body of literature demonstrates that, irrespective of the mechanism of injury, obesity has effects on the progression of the condition that tend to complicate cases of serious trauma and increase morbidity and mortality. The aetiological processes behind the development of complications are less well defined, although anatomic, physiologic and immunological dysfunction have all been theorised to play a role.

In a study by Haricharan and colleagues (2009), being overweight or obese increased the risk of pneumonia, sepsis and renal failure among trauma patients by 2 to 4 times when compared with normal-weight patients. This is consistent with higher rates of post-injury pneumonia, sepsis, renal failure, and multiple organ dysfunction previously reported in obese trauma patients (Brown et al. 2005; Ciesla et al. 2006). In combination with other risk factors, the likelihood of deep venous thrombosis (blood clots which can be harmful or lethal, particularly if they are carried to the lungs) is increased in obese trauma patients (Bendinelli & Balogh 2008; Sharma et al. 2007).

BMI was found to be an independent risk factor for early respiratory complications of injury cases and increased the need for and duration of invasive ventilation (Bochicchio et al. 2006; Dossett et al. 2008; Reiff et al. 2007; Sifri et al. 2008). Newell and colleagues (2007) hypothesised the higher rates of respiratory failure they observed could be associated with obesity-related underlying respiratory disorders such as sleep apnoea, obesity hypoventilation syndrome and compromised respiratory physiology.

Byrnes and colleagues (2005) found no difference in respiratory failure or cardiovascular complications, but a higher rate of renal failure post-injury in obese patients compared with non-obese patients. Others have shown that obesity increases the risk for renal failure (Knight et al. 2007).

Ciesla and colleagues (2006) found an increased risk of multiple organ failure (MOF) among obese injured patients, with nearly three-quarters of their obese MOF patients having early onset (within 72 hours of injury). They demonstrated that MOF was 1.81 times more likely to develop in obese patients than non-obese patients. This, they hypothesised, was related to post-injury inflammatory processes which are accentuated by the inflammation-promoting effects of obesity.

4 Obesity and workplace injury

Some injuries are sustained by people while they are working. Worker obesity has been considered a potential risk factor in part of the literature on work-related injuries. That literature is the main subject of this chapter.

In most parts of this report, attention is directed at the effects of obesity on the risk, patterns or consequences of injury sustained by obese people. For workers in some occupations, such as nursing, the obesity of other people might be a risk factor for injury. That is the second subject of this chapter.

Workers' obesity and injury

There have been a limited number of studies on the role of obesity in the modification of risk of workplace injury. There is evidence that obesity increases the risk of certain work-related injuries such as musculoskeletal disorders, heat stress, transportation accidents and vibration- induced injury (Pollack & Cheskin 2007; Schulte et al. 2007) and that traumatic workplace injuries increase with increasing BMI (Froom et al. 1996).

In a study of more than 7,000 workers at aluminium manufacturing plants in the United States, the odds of sustaining injury were raised in the overweight group (compared with normal-weight workers), higher in the obese group and highest in the very obese group, in which the odds of injury were more than doubled (Pollack et al. 2007). The presence of overweight or obesity had a stronger effect on the occurrence of acute sprains and/or strains than it did on other types of injury.

Work-related musculoskeletal injuries typically associated with obesity are disorders of the lower back (Fransen et al. 2002; Hagen et al. 2002; Ostbye et al. 2007), lower extremities (Coggon et al. 2000; Cooper et al. 1998; Felson et al. 1997; Lievense et al. 2002; Manek et al. 2003; Peltonen et al. 2003) , wrists (Geoghegan et al. 2004; Oliveria et al. 1999; Roquelaure et al. 2001) and shoulder (Miranda et al. 2001). For obese workers, repetitive movements, such as kneeling, squatting and typing, compound cumulative injuries such as carpal tunnel syndrome or osteoarthritis (Coggon et al. 2000; Kortt & Baldry 2002).

Obesity has been identified as an important risk factor for exertional heat illnesses (EHI) which, as effects of external causes, are often grouped with injuries. A number of studies have found an increased risk of EHI among obese military recruits and athletes (Gardner et al. 1996; O'Donnell 1977; Schickele 1947; Stallones et al. 1957). In a case-control study of Singaporean military personnel with heat disorders, obese soldiers (BMI > 27kg/m2) were at a 3.5 times greater risk of heat disorders during physical training (Chung & Pin 1996). In US military recruits, Gardner and colleagues (1996) demonstrated a threefold increase in the risk of developing EHI in recruits in the highest quartile for BMI (> 26 kg/m2). They hypothesised that a larger body mass resulted in higher heat production during exercise, and a lower ratio of surface area to body mass reduced heat loss resulting in an increased susceptibility to EHI. Similarly, a study of underground miners identified that a BMI > 27 kg/m2 was associated with an increasing number of heat exhaustion cases (Donoghue & Bates 2000).

Obesity arises from complex social and biological phenomena. While it is often perceived as the result of an individual's behaviours, aspects of employment such as shiftwork and long working hours have been found to be associated with elevated body weight and obesity (Schulte et al. 2007).

A section in Chapter 2 considers the elevation of crash risk among drivers (including professional drivers) who are obese, particularly when obstructive sleep apnoea is present. Fatigue due to disrupted sleep is thought to be the main mechanism.

Effect of obesity on use of safety equipment

Protective clothing and equipment may be less likely to be worn by obese workers, or be less suitable for them because of poor fit or reduced availability, potentially leaving the worker vulnerable to injury (Hsiao et al. 2003). This might partly explain the findings that obesity is a factor for occupational heat stress in a range of occupations (Maeda et al. 2006) and among those who have to wear protective clothing (Marszalek et al. 2004).

Similarly, limitations to the use of safety equipment, such as seatbelts, have been implicated in the increased risk of injury among obese transport workers involved in transport accidents (Lichtenstein et al. 1989; Schlundt et al. 2007).

Obesity and work absences

Studies indicate that obese workers are more likely to take sick leave and be less productive than non-obese workers (Finkelstein et al. 2007; Narbro et al. 1996; Ricci & Chee 2005). In Australia, analysis of the 2001 NHS data found that obese workers were more likely to be absent from work for a personal illness or injury than non-obese workers and the average absence was longer for obese employees (3.8 days) than non-obese employees (3.0 days). This equated to more than 4 million work days lost per year (AIHW 2010b). However, the extent to which absences were due to injury rather than other causes is not made clear in much of the literature on this topic.

Ostbye and colleagues (2007) reviewed worker's compensation claims over 8 years for an employee health insurance scheme and found a linear relationship between BMI groups and claims rates. The rate of claims for those with a BMI > 35 was twice that of normal-weight employees (11–12 vs 6 claims per 100 FTEs). Additionally, employees with the highest BMIs lost significantly more workdays than those of normal weight. 'Fall or slip' was the cause category most strongly related to BMI. Others have found that obesity has a significant positive association with lost work days, but the studies do not distinguish injury from other causes (Bungum et al. 2003; Moreau et al. 2004; Pronk et al. 2004).

Workers' injury risk due to contact with obese people

The main focus of this report is effects of obesity on the risk, patterns or consequences of injury sustained by obese people. In addition, the obesity of other people might be a risk factor for injury for workers in some occupations, such as nursing, in which there is an occupational requirement to lift or move patients or clients.

Caring for the obese patient is widely considered to have negative implications for worker safety (Cowley & Leggett 2010; Gallagher 2004; Humphreys 2007), although we did not find any quantitative statistical evidence on the effect of managing obese patients on the often high rates of back injury among nurses and other workers who must lift and move patients (Edlich et al. 2005). Despite the lack of statistical evidence of risk, there is a widely acknowledged need for special equipment for transporting very obese patients, as well as training in manual handling and biomechanics (Boatright 2002; Nelson et al. 2006; Trinkoff et al. 2003).

In an Australian survey of emergency department staff and patients, Kam and Taylor (2010) reported a significant increase in patient management difficulty for obese patients and the challenges of physical care, particularly in relation to positioning and mobilisation. Concerns also included increased staffing needs required for the care of obese patients, the availability and use of specialised equipment, and perceived safety issues, both for themselves and their patients.

5 Obesity, sport, physical activity and injury

This chapter presents evidence on the relationship between obesity and injury risk while undertaking physical activity, including sport. Physical activity is defined as any bodily movement produced by contraction of skeletal muscle that increases energy expenditure (Pate et al., 1995). Exercise is a subcategory of physical activity that is planned, structured, and repetitive and purposive in the sense that the improvement or maintenance of one or more components of physical fitness is the objective (Caspersen et al. 1985). Exercise includes virtually all physical training and sports activities, such as physical education classes, sports training and basic training in the military.

Physical activity and injury

Participation in sports and recreational physical activity involves a risk for injury. In Australia in 2002–03 there were 45,452 hospitalisations for sport and recreation related injury, accounting for 6.3% of all injury hospitalisations (Flood & Harrison 2006). The highest rate of hospitalised injury was for those aged 5–14 (791.5 per 100,000 participants), followed by those aged 15–24 (516.5 per 100,000 participants). Injuries to the lower limb (20.7%) were most common, followed by upper limb (19.1%) and head (18.5%). More than half (52.8%) of injury hospitalisations had fracture as the principal diagnosis. Falls were the most common mechanism of injury, accounting for 36% of cases. Risk per participant varies widely between sports, tending to be highest in contact sports, such as most football codes (Flood & Harrison 2006).

However, the majority of sport-related injuries do not require admission to hospital. In a prospective cohort study of non-elite sports participants in Western Australia, 70% of the participants sustained at least one injury over two playing seasons. While many of those injured required treatment from a health-care practitioner (78.3%), only 3.8% attended a hospital emergency department (Finch et al. 2002) and fewer would have been admitted to hospital. There may also be long-term consequences for those sustaining injury in sport, with studies showing increased osteoarthritis and joint replacement rates in retired athletes compared with the general population (Drawer & Fuller 2001; Golightly et al. 2009).

Physical activity and obesity

Obesity and physical inactivity are closely linked. Many studies focusing on children, as well as state and national physical activity surveys, have shown a relationship between obesity or high BMI and patterns of low physical activity (Ekelund et al. 2004; Janssen et al. 2005). It is difficult to determine whether obesity causes inactivity or inactivity causes obesity, although it is likely they drive one another. Studies that follow individuals over time (that is, longitudinal studies) are needed to investigate this. In a longitudinal study of 5,142 individuals followed for 15 years, Petersen and co-workers (2004) found that:

- physical inactivity at one point in time was not associated with the subsequent development of obesity
- the development of obesity was associated with subsequent decreases in physical activity levels.

Is obesity a risk factor for sports injury? What are the mechanisms by which obesity might contribute to increased injury risk? For children, and also for adults, a high BMI tends to be considered to be a risk factor for injury, on the basis that a large body mass, whether it be increased fat mass, or fat-free mass, produces proportionally high forces in joints, ligaments, and muscular structures.

The literature reviewed here has two aspects. First, a small thread in the extensive literature on sports safety is concerned with the effects of body mass on injury risk, types and outcomes. Second, population health measures to reduce obesity include efforts to increase physical activity. Some of the literature on that topic considers the injury risk of the activities, as well as their benefits for weight control and fitness.

Sports injury and body mass

Body mass is quite often studied as a potential risk factor for sports injury. It should be noted that athletes, particularly elite athletes, are likely to have higher muscle mass than most people. This will contribute to elevation of BMI values, though with different implications to the elevation of BMI due to high mass of fat, the situation in overweight and obesity.

Much of the literature on sports injury refers to body mass and does not distinguish between fat and lean mass. Rather, attention is often directed to the consequences of body mass (whether muscle, bone or fat) on injury risk in certain situations that arise in sports. The particular situations differ between sports. In contact sports, for example, the mass of players affects the energy dissipated during collisions between players. This affects the potential for harm, lighter players tending to do worse than heavier players. In sports requiring sudden stopping or turning, a player’s mass can have important effects on the load borne by his or her joints, ligaments and tendons. In this situation, lighter players may do better than heavier players.

The literature reviewed here includes studies dealing with effects of body mass on injury as well as studies in which the focus is more clearly on obesity as conceived in general public health literature (that is, elevated BMI chiefly due to fat).

Young people

Evidence on effects of body mass on injury risk in children and young people varies between sports and sometimes within them, limiting the potential for general conclusions. In collision sports (American football being the most often studied example), players who have a greater BMI are less likely to be injured in a collision than the lower BMI player (Malina et al. 2006). However, several other studies have reported an increased rate of injury among heavier players (Emery 2005; Goldberg et al. 1988; Kaplan et al. 1995; Stuart et al. 2002) or players with a high BMI (Gomez et al. 1998; Tyler et al. 2006).

In ice hockey, another collision sport, two studies have shown that lighter players were more likely to be injured (Brust et al. 1992; Roy et al. 1989). This was attributed to marked differences in strength and impact forces between children of different sizes.

Several studies of American high school student participants in sports (chiefly players of American football) found no significant differences in injury risk between obese and non-obese teenagers (Abacherli et al. 2009; Gomez et al. 1998; Kaplan et al. 1995; Knowles et al. 2009; Lowry et al. 2007; Turbeville et al. 2003a; Turbeville et al. 2003b). However, two studies reported that risk of non-contact ankle sprains in high school football players and athletes was higher if they were overweight (McHugh et al. 2006; Tyler et al. 2006).

A 3-year retrospective review of injured US high school athletes from a nationally representative sample of 100 US high schools found that patterns of injury also varied with BMI. Fractures were more prevalent in the small group of underweight injured athletes and knee injuries were prevalent in the obese group, both compared with the normal-weight group (Yard & Comstock 2011).

It has been shown that heavier young athletes have poorer balance and posture (Deforche et al. 2009) and it has been hypothesised that obese athletes may be less able to maintain their balance during collisions (Yard & Comstock 2011). This principle may not apply in some sports: in gymnastics, where a smaller body size is optimal, a higher BMI is associated with a lower power-to-weight ratio and has been shown to result in an increased injury risk (Lindner & Caine 1993; Steele & White 1986; Wright 1998).

Adults

This section includes literature on injury and obesity or overweight in the context of formal sport and other forms of physical activity or exercise undertaken by adults.

Studies involving military recruits are referred to as the majority of injuries sustained by the recruits are related to physical training. Jones et al. (1993) found high BMI and high body fat content to be risk factors for sustaining lower extremity injury among military recruits. Men in the highest quartile for BMI had a threefold increase in the incidence of all lower extremity injuries compared with the middle 50% of recruits. Men in the upper quartile for body fat, as measured by a sum of four skinfolds, had nearly twice the incidence of injury compared with the remaining 75% of men. Similarly, male military recruits with a larger BMI had a significantly increased risk of sustaining a lateral ankle sprain (Milgrom et al. 1991).

Conversely, a number of studies have reported no association between body size and physical activity related injury. Knapik and co-workers (2001) did not find height, weight, or BMI to be risk factors for injuries among female and male military recruits, although poor physical fitness was a significant contributor to injury risk. Likewise, the incidence of ankle injury among college athletes participating in soccer, field hockey and lacrosse was not related to BMI (Baumhauer et al. 1995; Beynnon et al. 2001). Among elite and recreational basketball players there was no significant difference in height or weight between players who incurred ankle injury and those who did not (McKay et al. 2001). Similarly, Bennell and colleagues (1996) found no difference in height, weight, total lean mass, or body fat among male and female track athletes who sustained stress fractures compared with those who did not. Furthermore, in an injury risk factor study of female soccer players, Ostenberg and Roos (2000) did not find BMI to be a risk factor for injuries among female soccer athletes followed over a playing season. Wiesler et al. (1996) did not find BMI to be a risk factor for lower extremity injury among dancers.

In a position statement on exertional heat illnesses (EHI) during training and competition, the American College of Sports Medicine (Armstrong et al. 2007) identified a number of intrinsic and extrinsic risk factors that contribute to EHI. Obesity and the wearing of protective clothing which restricts evaporation were two factors reported to increase risk of EHI among athletes.

Physical activity, obesity and injury risk

Regular physical activity is widely advocated by public health authorities (DHAC 1999; DOHA 2010), in part because substantial epidemiological, clinical, and basic science evidence shows that physical activity and exercise training ameliorate the development of a range of chronic diseases (Adams et al. 2006; Bogers et al. 2007; Gregg et al. 2005; Whitlock et al. 2009). Physical activity is also advocated to reduce body weight. A systematic review of evidence on 'Exercise for overweight or obesity' found that exercise adds to weight loss achieved by diet alone and that high-intensity exercise is better than low-intensity exercise for weight loss (though a significant difference was only found if dietary change was not also used) (Shaw et al. 2006).

While physical activity has health benefits and can contribute to weight loss, it can also transiently increase the risk of injury.

As obesity is common in the Australian population and obese and overweight people are encouraged to undertake physical activity for health or weight loss, it is reasonable to ask whether the evidence on which such advice is based takes account of injury risk, and whether that differs between obese and non-obese participants. We looked for literature on these matters. We found none that was directly relevant and a little that was indirectly relevant, which is reported here.

A Cochrane systematic review of 'Interventions for promoting physical activity' focused primarily on the effectiveness of the 29 trials that met its inclusion criteria (Hillsdon et al. 2005). The review authors also assessed whether the trials had studied certain aspects of the safety of the interventions, including whether the trials had reported on injury risk as a potential complication of the interventions. The reviewers found that only 8 of the 29 trials reported the effect of the interventions on injury risk. Of the 8 that did, 7 found no significant difference in fractures, sprains or falls between intervention and control groups, and 1 found some evidence of increase. Hillsdon et al. did not report whether the trials had taken account of obesity. Similarly Kelly et al., in their review of exercise for overweight or obesity did not mention injury specifically but reported that, 'No data were identified on mortality, morbidity or adverse events or quality of life' among the 41 trials studied.

Few studies were found in which obese people undertaking vigorous physical activity were assessed for injury risk. In a small randomised controlled trial of kung-fu training in obese adolescents (Tsang et al. 2010), 2 of the 20 participants experienced an adverse event during the 6-month intervention, and these were both fall related.

The Australian physical activity guidelines (DOHA 2010) were informed by discussion papers that encompassed evidence for injury risk associated with physical exercise. The guidelines recommend regular physical exercise for health benefits and are framed, among other things, by age. The guidelines for infants and children aged under 5 refer to advice ensuring a safe environment for activities. The guidelines for older children include the advice that 'Any activity is good for you' and '…remember to always take precautions to avoid injury', although there is no suggestion that the precautions might include choosing activities that carry less rather than more risk of injury, or of informing children and parents about the risks. The discussion paper underlying the current guidelines for children mentions injury as a risk of physical activity participation, but does not quantify injury risk or how risk differs between activities (Trost 2005). Nor does it discuss the possibility of interaction between injury risk and obesity.

The activity guidelines for adults include the argument that regular physical activity can reduce the risk of injury (by helping to 'build and maintain healthy bones, muscles and joints'). The guidelines concerning moderate-intensity activity do not mention risks of activities. Guideline 4 for adults, concerning vigorous activity, does not mention injury risk directly, but recommends that certain groups of adults should seek medical advice and also recommends warm-up, cool-down, stretching and a gradual build-up from an inactive level. The scientific background report for the guidelines mentions injury as a potential consequence of activity; the authors present this as only being a substantial problem in the context of 'excessive exercise' and conclude that 'the benefits of regular, moderate-intensity physical activity outweigh any risks' (Egger et al. 1999). However, like the report concerning children's activity, this paper does not quantify injury risk, assess variation of injury risk between activities, nor consider whether injury risk of activity is raised in the presence of obesity.

The recommendations for older people are similar, though with a stronger emphasis on taking account of the current health state of the person. The discussion paper underlying these recommendations considers injury as a possible risk of physical activity by older people (Sims et al. 2006). The authors cite a 1999 review of trial-based evidence and the experience of a large-scale exercise program in Scotland as the basis for their conclusion that 'the risks of sedentary behaviour appear to outweigh those associated with physical activity'. As with the other reviews, no specific attention is given to possible differences in injury risk between activities, nor to altered injury risk in the presence of obesity. Tailoring exercise to individual circumstances is seen as desirable, and injury risk and obesity could be factors considered when doing so.

6 Discussion

Australia has an obesity problem. Well established co-morbidities associated with obesity affect the health and welfare of the Australian population and increase the demand for health services. Little consideration has been given to the relationship between obesity and injury and how that relationship contributes to the burden of mortality and morbidity in Australia.

Injury, on its own, is the leading cause of mortality for males aged between 1 and 44 and is estimated to result in the third-highest health burden in Australia in terms of years of healthy life lost (AIHW 2010a).

This overview of the literature identified a small but growing number of reports and peer-reviewed publications that have investigated the relationship between obesity and injury. Findings are mixed but, on balance, evidence suggests that obesity usually increases the risk of injury, alters the pattern of injury and tends to complicate recovery. Readers are cautioned that the strength of the evidence of an association between obesity and injury identified in the overview of the literature is yet to be rigorously evaluated.

The probability of falls, trips or stumbles, and resulting musculoskeletal injury, tends to rise with obesity. This has been found in the general population, in sport and in the workplace. The harmfulness of the increased risk of falls by obese people may be somewhat offset by a possible protective effect of fat mass as cushioning, and by increased bone density in the weight-bearing joints of obese people. There is evidence for increased risk of osteoarthritis and other overuse injuries among obese people.

The interaction of obesity and injury risk in children is complex and evidence limited. Falls risk is higher for obese children, probably increasing rates of face, tooth and musculoskeletal injuries. Obesity is also a risk factor during pregnancy with increased rates of injury to mother and baby. The relationship of body mass and injury risk during sport is complicated by the diversity of sporting activities and by the fact that muscle mass, not fat, is raised in many athletes.

Sleep apnoea, which increases risk of road injury, is strongly associated with obesity.

Workers' obesity has been found to be associated with elevated risk of workplace injury.

The rising prevalence of obesity is widely seen as a risk factor for injury of nurses and workers in other occupations that require lifting people. While direct evidence of risk was not found, managing the suspected risk is the subject of numerous occupational health and safety interventions.

Of particular relevance to the health sector is the finding that obesity affects outcomes after injury. Average length of stay in hospital is significantly longer for obese injured patients than for their leaner counterparts. Greater requirements for respiratory support have also been shown for injured obese patients relative to the non-obese. Furthermore, obese injured patients are more likely to suffer certain complications during the period of care following injury. Risk of death after serious injury appears to be raised by obesity, though findings are mixed concerning the most severely injured cases.

Exercise is advocated for health reasons, including reduction of obesity. Since obesity has associations with injury, it is reasonable to ask whether advice concerning exercise has taken account of this factor (for example, providing additional advice concerning safe exercise for obese people). We found no indication that it had.

Data sources

The literature found for this review was not specific to Australia, though findings concerning effects of obesity on patterns of injury are likely to be applicable generally. In large part the limited evidence found reflects the lack of data on obesity in routine data sources. In particular, the National Hospital Morbidity Database (NHMD) in Australia does not include information on BMI, though weight and height are commonly measured for hospital admitted patients. Hence, none of the many reports based on the NHMD provides an analysis of injury data mechanism and patterns of injury by obesity status.

Diagnosis codes in the NHMD might provide an alternative to direct measures of obesity and certain specialised data sources and surveys might provide better data on obesity, though only for the severely injured patients treated by specialised trauma services.

What follows is an assessment of data sources and types of investigation that can advance the understanding of obesity and injury in Australia, to guide policy and program responses.

National Hospital Morbidity Database (NHMD)

Most serious injuries in Australia result in hospital admission, unless they are rapidly fatal. The National Hospital Morbidity Database (NHMD) contains records of separation from hospital (separation is the formal or statistical process by which an episode of care of an admitted patient ceases) for nearly all hospitals in Australia. NHMD records include diagnoses, procedures undertaken, and certain characteristics of the episode in hospital (for example, its duration) and of the patient (for example, age and sex).

The key limitation of the NHMD for the assessment of effects of obesity on injury is that the NHMD currently lacks items on weight and height. However, these data are often recorded (and sometimes measured) during a hospital admission and so it might be feasible to add the items to the NHMD. This would probably be of value generally, not only for analysis of obesity and injury. Assessment of the feasibility and acceptability of adding these items is warranted.

The NHMD does include codes for principal and additional diagnoses of admitted patients. Some of these codes refer to obesity. Matter et al. (2007) conducted a study in which records with these codes were compared with other records. A similar study could be conducted in Australia, based on ICD-10-AM codes in the NMDS. Such a study can be expected to have similar limitations to that by Matter et al., identifying only some obese inpatients. Woo et al. (2009) compared the effect of applying criteria similar to those used by Matter and colleagues to a method based on records of weight and height in hospital files. They found that only 5.5% of children in a US hospital whose measured height and weight implied obesity could be identified as obese on the basis of ICD codes in discharge data. (Woo et al. 2009).

Should it be expected that the presence of obesity or overweight will be reflected in the ICD codes of injury cases in Australia? More particularly, are ICD codes likely to reveal cases in which obesity or overweight is an incidental characteristic rather than a primary reason for admission? For example, when a person with a BMI of, say, 32 is admitted to hospital because of a fracture sustained in a motor vehicle crash.

The Australian Coding Standards (ACS) that guide the application of ICD-10-AM codes to Australian hospital data allow for the coding of additional diagnoses (NCCH 2008). An additional diagnosis is defined as a 'condition or complaint either coexisting with the principal diagnosis or arising during the episode of admitted patient care…'(ACS 0002). The guidelines specify that conditions should only be coded as additional diagnoses if they are 'significant in terms of treatment required, investigations needed and resources used in each episode of care'.

That threshold might often be met when a morbidly obese person is admitted, but it is much less evident that it would be met in the presence of overweight or moderate obesity. Most of the evidence in this report refers to distributions in populations. For example, obese injured people tend to require a longer stay in ICU than non-obese injured people. At the level of an individual case the period might be long, but not so remarkably long that it prompts mention in the record with attribution of the long stay to obesity, thus satisfying the requirement for coding obesity as an additional diagnosis in this case.

Certain conditions that would not normally meet the ACS standard for coding an additional diagnosis have been designated as warranting coding on a routine basis, without a requirement that their presence has significantly affected management of the patient during the admitted patient episode. Examples are pregnancy or HIV/AIDS. Obesity, per se, does not have this status, though the coding standard for diabetes includes information on criteria for coding obesity and overweight.

No study was found of the extent to which obesity in patients admitted to Australian hospitals was represented in the NMDS (that is, an Australian study similar to that of Woo et al. 2009).

Survey data

Several surveys undertaken in Australia might be useful in examining relationships between obesity and injury.

- National Health Surveys (NHS): these surveys are conducted by the ABS about every three years and are designed to collect information on the health status of a representative sample of the Australian population. Information about short-term and long-term medical conditions, consultations with health professionals, and other actions recently taken in regard to health is collected. Information is also collected on health-related lifestyle and risk factors, such as diet, physical activity and smoking (ABS 2009b). Self-reported height and weight have been collected in all of the surveys to date. In addition, the height and weight of a sample of respondents was measured in two of the surveys. BMI was calculated from these height and weight measures and reported. Most instances of the NHS included questions on injury and the circumstances in which it occurred. Unfortunately, the most recent NHS obtained less information on injury than earlier ones. The Australian Health Survey 2011–12, for which data collection began in mid-2011, includes measured height and weight and information on physical activity.

- Physical activity surveys: Several national surveys and numerous state-based surveys have been conducted since 1988. Table 1 summarises these surveys from 1997 onwards. The weight and height data for most of these surveys were obtained by the use of questionnaires, rather than measurement. Self-reported height and weight are subject to limitations, particularly the fact that respondents tend to report values that are more 'desirable' than the true values (AIHW 2003; Merom et al. 2004.) Nevertheless, the surveys provide the best evidence base currently available.

  The most commonly used questionnaire instrument in Australia has been the Active Australia Survey (AAS). This was developed in 1997 and has been the standard instrument since this time (AIHW 2003). At least six national surveys and 30 state-based surveys have used the AAS instrument. Before 1997 there were at least three national surveys that asked about physical activity patterns using other instruments. These assess leisure, occupational and household physical activity patterns as well as collect self-reported data on height and weight. Analysis of physical activity patterns and body size in relation to injury has not been reported
- Population-based cohort studies: These are projects in which a population sample is recruited, baseline information obtained, and the people are followed up at later dates. The information collected varies between projects but usually includes a range of health indices as well as height and weight and often at least some information on injuries. Examples of such projects are the Australian Diabetes, Obesity and Lifestyle (AusDiab) study, the 45 and Up study, and the Australian Women's Longitudinal Health Study.

Table 1: Australian national and state-based physical activity surveys, Australia 1997–2009

	National	NSW	Vic	Qld	WA	SA	Tas	ACT	NT
1997	National Physical Activity Survey			Health Survey					
1998		Health Survey				Physical Activity Survey			
1999	National Physical Activity Survey		Population Health Survey		Health & Wellbeing Surveillance System				
2000	National Physical Activity Survey & AusDiab Study (1999–2000)								
2001	National Health Survey		Population Health Survey	Health Survey		Physical Activity Survey			
2002		Health Survey	Population Health Survey		Health & Wellbeing Surveillance System				
2003		Health Survey	Population Health Survey						Physical Activity Survey
2004	National Health Survey (2004–05)	Health Survey	Population Health Survey	Health Survey		Physical Activity Survey			
2005		Health Survey	Population Health Survey						
2006		Health Survey	Population Health Survey	Health Survey	Health & Wellbeing Surveillance System				
2007	National Health Survey (2007–08)	Health Survey	Population Health Survey			Physical Activity Survey		General Health Survey	
2008		Health Survey						General Health Survey	
2009		Health Survey					Population Health Survey	General Health Survey	

Other sources

Some other databases might be used to explore the relationship between obesity and injury. For example, disease or health service specific databases that collect information on height and weight measures as well as health data. For example, the Australian New Zealand Intensive Care Society collects detailed data on all patients admitted to intensive care units in Australia and New Zealand. In 2007, height and weight were added to its minimum data set so that BMI could be determined for patients requiring critical care.

Suggested investigations

The previous section surveys data sources that might be relevant to investigation of this issue. This final section outlines how the available data could be used to provide better insight into the relationship of obesity and injury in Australia, and into related health burden.

Effect of obesity on requirement for hospital admitted patient services for injury

The literature reviewed in Chapter 4 shows that injured people who are obese are more likely than normal-weight patients to require certain aspects of care, or require them for a longer period. Available sources do not provide a specific indication of the extent or nature of the impact of obesity on hospital inpatient services in Australia.

If such information was available, it could be used to assess cost and impact and to plan responses. If obesity was confirmed to have a non-trivial impact on type or cost of care required by injury cases (or by other types of case), then consideration might be given to taking account of obesity in Casemix weights.

As noted above, the NHMD provides readily accessible data on nearly all cases of injury admitted to hospitals in Australia. However, the NHMD does not currently include data on weight, height or BMI. The NHMD does provide data on case diagnoses and on procedures performed during a stay in hospital, which are coded according to the Australian clinical modification of International Classification of Diseases, the ICD-10-AM (NCCH 2006).

A preliminary evaluation of the usefulness of the NHMD for this topic requires careful examination of all ICD-10-AM codes for relevance to obesity and an assessment of the pattern of use of these codes within the NHMD. An example of such an ICD-10-AM code is E66.9 Obesity (simple). It should be noted that ICD-10-AM coding in the NHMD is intended to record injuries and diseases that were reasons for admission to hospital, or significantly affected the treatment required. Obesity will sometimes fit that requirement (for example, if an obese person is admitted for a gastric bypass operation) and it is these cases that are most likely to be available for this initial analysis of characteristics such as length of stay.

The ACS suggests that analysis of the current NHMD, alone, is not likely to provide a good indication of the burden on hospitals attributable to overweight and obesity among people admitted because of injury, though it could provide information about cases in which obesity or its treatment is the reason for admission, and perhaps about cases admitted for other reasons where obesity was a prominent issue (for example, because of its severity).

A better estimate of that burden could be achieved by means of a study in which a sample of hospital records is inspected to:

- assess whether patient weight and height were recorded and whether these were measured in hospital, or the patient provided the values
- record the height and weight, if present
- record other information from the record that is relevant to patient treatment and outcome, and not available from the NHMD.

Analysis of this additional information along with NHMD data for the same cases would reveal the availability of height and weight in hospital records and provide information on the distribution of BMI for the case types included in the sample. Depending on the size of the sample, the study could also provide information on the effect of BMI on length of stay, the occurrence of complications of care, and other factors relevant to burden and outcome.

Effect of obesity on injury occurrence, patterns and consequences

A study of the type just described would provide information on the effect of obesity on requirements for hospital care, if serious injury has occurred. The findings of some parts of this review indicate that, in some circumstances, obesity also influences risk and pattern of injury occurrence. Investigation of the effect of obesity on injury occurrence, patterns and consequences in Australia requires a different type of investigation.

Confirmation and further investigation of findings of this review, for the Australian population, can be based on sources mentioned earlier in this chapter. Population surveys that record the occurrence of injury and the presence of obesity can be analysed in a way that focuses on the relationship between these factors. Surveys in which height and weight are measured (rather than reported by subjects) are particularly valuable. Of the currently available large national surveys, the 2004–05 National Health Survey provides the best information on injury. The 2011–12 Australian Health Survey should provide good information on weight and height, but will provide little information on injury. Analysis of these surveys has potential to reveal the effect of obesity on risk of injury, and some potential to assess the effect of obesity on whether injury results in admission to a hospital. The potential to assess effect on hospital admission is limited because, despite the large size of these national surveys, the number of subjects who report recent injury resulting in hospital admission is small.

A second type of study is feasible in the parts of Australia in which population health data linkage systems are in place, especially if a large prospective cohort study can be joined to the system. The conditions for such a study appear to be best met in NSW, where the large 45 and Up cohort study can be linked with hospital admitted patient data and other administrative data. Data from the 45 and Up project, most importantly BMI, would be linked to hospital admitted patient data to allow analysis of the effect of overweight and obesity on the incidence of admitted injury, and on hospital service utilisation, complications arising during care, and other factors. This approach would be able to take account of all episodes of hospital care for each person. Studies of this type have much potential, but require careful planning and costing, which are the necessary first steps. At least one project, already approved to make use of the 45 and Up study, has potential to provide relevant information (Banks et al. 2011).

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