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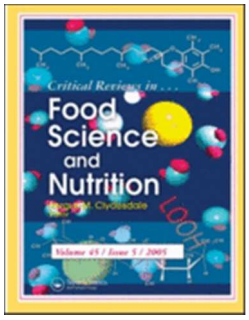

PREVALENCE AND CHARACTERISTICS OF OVERWEIGHT AND OBESITY IN INDIGENOUS AUSTRALIAN CHILDREN: A SYSTEMATIC REVIEW

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INTRODUCTION

There is growing international recognition of the need to address socio-economic disadvantage and poor health outcomes within Indigenous populations in developed nations including the United States, Canada, Australia and New Zealand. (Brown 2012) In spite of significant variation in history, culture, governance (e.g. treaties and degree of self-determination), geographical location and socio-political context, these populations continue to experience higher levels of disadvantage and poorer health outcomes than the general population in their countries. (Brown 2012) In 2008 the Council of Australian Governments (COAG) committed to addressing the health disparity between Aboriginal and Torres Strait Islander peoples (hereafter referred to as Indigenous Australians) and non-Indigenous Australians by adopting the *Closing the Gap* policy initiative. (Australian Human Rights Commission 2007; Council of Australian Governments 2008) Under this initiative, targets for closing the gaps across a range of health and wellbeing indicators were set, including targets for life expectancy and child mortality. The initiative has gained some success in achieving convergence for some child health indicators, most notably child death and immunization rates. Whilst funding for specific monitoring of the program has now been withdrawn, there has been some government investment in evaluating indicators for these targets. Looking across the set of health and wellbeing indicators for which measures are available, wide disparity remains, both in those of children (0-17 years) and adults (COAG Reform Council 2014). The life expectancy gap between Indigenous and non-Indigenous Australians is still 10.6 years (10.6 for males and 9.5 for females). (COAG Reform Council 2014) Obesity in Indigenous Australians is one of the main risk factors contributing to the health gap. (Vos et al. 2009) Overweight and obese children are more likely to become overweight and obese as adults but perhaps as important, risk factors such as poor diet and physical activity, established in childhood, often persist into adulthood. (Must & Strauss 1999; Nadeau et al. 2011) The data supporting the previous statement, in the main, reflect non-Indigenous populations and as yet we know neither how overweight and obesity in Australian Indigenous children plays out in adult life, nor what comprises appropriate anthropometric cut-off points for this population. (Gracey et al. 2007)

Data gaps compromise our ability to devise appropriate interventions to prevent children becoming overweight and support treatment of children who are already overweight or obese. Given the tendency for Aboriginal people to exhibit central adiposity (Australian Bureau of Statistics 2013a; Piers et al. 2003) and their increased risk of cardiovascular disease and diabetes, (Wang & Hoy 2005, 2013) it would appear that effective strategies to support healthy eating and physical activity in Indigenous Australian children should be one of the priorities if the gap in life expectancy between Indigenous and non-Indigenous populations is to be closed. Although the National Preventative Health Taskforce provided some key approaches, (Boffa et al. 2009) Australian Governments have, on the whole, been slow to act in designing policies specifically aimed at supporting healthy eating in the Indigenous population (Browne, Hayes & Gleeson 2014). As we write this paper, the 10 year national Indigenous nutrition strategy and relevant state strategies have expired and have not been replaced by new policies. (Browne, Hayes & Gleeson 2014) To develop culturally appropriate and effective interventions for preventing and treating obesity in Indigenous Australian children, we require an understanding of the extent of the problem of obesity and overweight, as well as their

determinants. Until recently there was a paucity of data on obesity in Indigenous Australian children. (Australian Institute of Health and Welfare 2009a) National data has only recently become available. (Australian Bureau of Statistics 2013a)

The aim of this systematic review is to examine 1) the prevalence of obesity and overweight in Australian Indigenous children, and 2) the pattern of overweight and obesity prevalence in Indigenous Australian children with respect to gender, age, living in a remote area and birthweight. This will enhance our knowledge of where to target public health interventions and policy, and/or support the design of new studies to address the current gaps in evidence.

METHODS

An *a priori* review protocol was developed and registered on the PROSPERO International prospective register of systematic reviews (http://www.crd.york.ac.uk/PROSPERO; registration number CRD42014007626). This provides full details of the methods used. There were no changes to the protocol during the review.

Inclusion criteria

The inclusion criteria were studies involving Indigenous Australian children aged 0 to 17 years without a diagnosed disease. The outcomes were prevalence of obesity and/or overweight as defined by internationally recognised quantitative measures of overweight/obesity for children. In adults, the most commonly accepted definitions of overweight and obesity are a body mass index (BMI) of greater than 25 and 30 mg/kg^2 , respectively. International Task Force on Obesity (IOTF) have defined BMI age-and-gender specific z-score cut-off points for children which correspond to these values,(Cole et al. 2000) however other definitions are used and studies using other measures were included in the review. All study designs and publication types were considered. If an eligible study was identified only in abstract form, authors were contacted to enquire about full study publication. Articles were excluded if they did not report overweight and obesity as prevalence (e.g. reported BMI only as a continuous outcome), did not report prevalence measures for Indigenous children separately from other children, did not define the measure of overweight/obesity used, or did not use age-appropriate measures of overweight and obesity.

Search and study selection

In order to capture current prevalence data, English language articles published January 2003 to 16 January 2014 were identified using the databases EMBASE, MEDLINE and Scopus, Cochrane Database of Systematic Reviews, Database of Abstracts of Reviews of Effects, NHS Economic Evaluation Database, and Johanna Briggs Institute library. In process-citations for 2013-2014 were identified through PubMed. Terms and indexing used included (but were not limited to) obesity, obese, overweight, adiposity, anthropometric measures, juvenile, child*, teenage, adolescent, indigenous, aborigin*, Australia*. Hand searching for grey literature was performed through five targeted websites including Health Infonet, ATSI Health, and the Australian Institute of Health and Welfare (AIHW). Reference lists of included articles were checked for additional citations. The full search strategy is available on PROSPERO.

Titles and abstracts of all citations were initially screened by one author (SD) to identify articles meeting the inclusion and exclusion criteria, with a second author independently screening 11% of citations. Abstracts mentioning BMI, overweight, obesity or anthropometric measures in Australian children were selected for full-text review to check for

subgroup data on Indigenous children. Abstracts mentioning BMI and Indigenous or socioeconomic status as correlates for other outcome data (i.e. where these factors were used only for adjustment in a regression analysis of a separate outcome) were excluded on abstract. The full text of all unclear and included studies was assessed independently by two authors.

Data extraction

Data were extracted into a pre-determined proforma by one author and checked for coverage and accuracy by a second. Data items extracted were descriptive detail relating to the publication (e.g. authors, institution etc.) and the study (e.g. study design, sampling method, setting etc.). Full details are available online. Characteristics recorded were ATSI status, age, gender, geographical location (e.g. urban, rural, remote, very remote) and birthweight. The outcomes recorded were the prevalence (%, n/N and reported measure of variance) of obesity and/or overweight overall and in subgroups defined by: age, gender, geographical location (remoteness) and birth weight. Outcomes for non-ATSI populations were not extracted as they were beyond the scope of this review.

Where a study reported total sample size and prevalence only, the numerator was back-calculated and recorded. Similarly, where rates for obesity and overweight were reported separately, they were summed to obtain the prevalence of overweight or obesity combined.

Risk of bias assessment

Study quality was appraised independently by two authors using the first nine items of the Prevalence Critical Appraisal Tool. (The Joanna Briggs Institute 2014) The tenth (final) item of this tool was considered not applicable because all predefined subgroups were objective. A sample size of 289 or greater was considered adequate based on an expected prevalence of 25%, equivalent to that of all Australian children. (COAG Reform Council 2013) Recruitment via health services or schools was considered to have inherent selection bias, for example due to a greater proportion of children with suboptimal health utilising health services and absenteeism in schools.

Data analysis and synthesis of results

A meta-analysis of prevalence estimates of overweight or obese was precluded by significant heterogeneity (I^2>92%). Multiple different definitions of obesity and/or overweight were used in the different studies, depending on the measurement method used (see Table 1). The heterogeneity remained when studies were stratified by prevalence measurement method, study quality, population sampling method or remoteness (I^2>71%). Instead, findings were synthesized in a narrative summary of the studies, with the highest quality studies given greater emphasis.

RESULTS

Search and study selection

The literature search identified 1670 citations after duplicate removal. Based on title or abstract, 1407 citations were excluded and 263 articles reviewed in full text of which 230 were excluded. Studies that met the inclusion criteria that were excluded were duplicate study reports, (Australian Institute of Health and Welfare 2008a; Cinelli & O'Dea 2009;

Haysom et al. 2009c; Sayers et al. 2009; Valery et al. 2009) reports in which the authors indicated the data should not be used as a prevalence measure (Australian Institute of Health and Welfare 2008b, 2009b) and one study in which the prevalence data was provided in graphical form only. (Australian Institute of Family Studies 2013) The study selection process is shown in Figure 1.

Risk of Bias

Methodological quality of the included studies for the estimate of obesity prevalence varied widely. Of the nine quality appraisal items, four studies met six or more items (these studies were considered of high quality), 13 studies met 3 to 5 items (fair quality) and four studies met less than three items (considered low quality). Few studies (6/21) were representative of the target population of the study (Australian Bureau of Statistics 2013a; Ferrar & Olds 2010; Hickie, Douglas & Ciszek 2013; O'Dea 2008; Schultz 2012; Wake et al. 2007), or recruited indigenous children in an appropriate way (8/21) (Australian Bureau of Statistics 2013a; Haysom et al. 2013; Hickie, Douglas & Ciszek 2013; O'Dea 2008; Schultz 2012; Thurber 2012; Webster et al. 2013; Wolfenden et al. 2011) to provide a representative sample. The sample size was adequate to provide an estimate of the overall prevalence of overweight/obesity in 12 studies. (Australian Bureau of Statistics 2013a; Haysom et al. 2009a; Hickie, Douglas & Ciszek 2013; Li, Li & Guthridge 2012; Mackerras et al. 2003; Nichols et al. 2011; O'Dea 2008; Queensland Aboriginal & Islander Health Council 2013; Schultz 2012; Singh, GR & Hoy 2003; Spurrier et al. 2012; Thurber 2012) Study characteristics (i.e. the Indigenous study subjects and the setting) were described in terms of at least two of age, gender, geographical location, birth weight in 13 studies. (Australian Bureau of Statistics 2013a; Black et al. 2013; Haysom et al. 2013; Haysom et al. 2009a; Heath & Panaretto 2005; Li, Li & Guthridge 2012; Mackerras et al. 2003; O'Dea 2008; Schultz 2012; Singh, GR & Hoy 2003; Thurber 2012; Valery et al. 2012; Webster et al. 2013) No studies had sufficient response rate and completeness of follow-up and data to provide a prevalence rate with sufficient coverage of the intended sample (≥80% of the sample approached for recruitment). Only three studies reported a measure of variance for the prevalence. (Australian Bureau of Statistics 2013a; Schultz 2012; Wolfenden et al. 2011) Most studies (17/21) used trained staff or a health worker or measured height and weight with a digital scale and stadiometer or other appropriate tool. (Australian Bureau of Statistics 2013a; Black et al. 2013; Ferrar & Olds 2010; Haysom et al. 2013; Haysom et al. 2009a; Heath & Panaretto 2005; Hickie, Douglas & Ciszek 2013; Kagawa et al. 2009; Mackerras et al. 2003; Nichols et al. 2011; O'Dea 2008; Schultz 2012; Singh, GR & Hoy 2003; Spurrier et al. 2012; Thurber 2012; Valery et al. 2012; Wake et al. 2007; Webster et al. 2013; Wolfenden et al. 2011)

Characteristics of included studies

Twenty-one studies, reported in 25 articles, were included. (see Table 1) Six studies sampled the Indigenous population directly, six accessed the population via health services and eight accessed the population via childcare centres or schools. One study was conducted in a specific subpopulation, ATSI youth in custody.

The majority (16/21) of included studies measured prevalence of obesity using criteria outlined by the International Task Force on Obesity (IOTF), which defines body mass index (BMI) according to age-and gender-specific z-score cut-points for children (Cole et al. 2000). Five studies used other methods to measure overweight and/or obesity prevalence namely percentiles of age-and-gender growth charts (Heath & Panaretto 2005; Mackerras et al. 2003;

Queensland Aboriginal & Islander Health Council 2013; Sellers, Singh & Sayers 2008; Webster et al. 2013) and overweight and obesity cut-offs of ≥+1 standard deviation (SD) (Schultz 2012) and ≥+2 SD BMI-for-age.(Haysom et al. 2009a; Haysom et al. 2009b; Schultz 2012)

Thirteen studies enrolled more than 250 subjects, while four reported on less than 100. All studies, except one (Haysom et al. 2013), enrolled a representative sample of male and female children. The studies included children over a wide range of ages (Australian Bureau of Statistics 2013a; Black et al. 2013; Ferrar & Olds 2010; Schultz 2012) or for targeted groups including preschool children (<5 years)(Nichols et al. 2011; Webster et al. 2013; Wolfenden et al. 2011), school entry age children (4-6 years)(Hickie, Douglas & Ciszek 2013; Li, Li & Guthridge 2012; Spurrier et al. 2012; Thurber 2012; Wake et al. 2007) and schoolchildren more broadly (5-17 years).(Heath & Panaretto 2005; Kagawa et al. 2009; O'Dea 2008; Queensland Aboriginal & Islander Health Council 2013; Sellers, Singh & Sayers 2008; Singh, GR & Hoy 2003; Valery et al. 2012) The time period covered by the data varied between 2012-2013 (Australian Bureau of Statistics 2013a) to 1992-1998. (Nichols et al. 2011)

Two national studies, the ABS 2013-2014 Australian Aboriginal and Torres Strait Islander Health Survey (AATSIHS) (Australian Bureau of Statistics 2013a) and the Longitudinal Study of Indigenous Children (LSIC) (Australian Government 2013; Thurber 2012) involved >1,000 Indigenous children with direct population sampling. The sampling frame for the AATSIHS study included Indigenous households identified in the 2011 Australian Census of Population and Housing (Australian Bureau of Statistics 2013b), covering all ages and areas of Australia but not individuals living in non-private dwellings (e.g. caravan parks or hostels) or small remote communities. Under-coverage was estimated at 4% of Indigenous people. (Australian Bureau of Statistics 2013b) LSIC involved purposeful sampling of one child per family with clustered sampling from 11 geographical sites. (Thurber 2012) Areas of extreme isolation and Torres Strait islander children were underrepresented.

Overall prevalence of overweight / obesity

The prevalence of overweight plus obesity varied substantially from 11% to 54% with 6% to 35% overweight and 1% to 22% obese, with different studies using different definitions. (see Table 2) Two studies using a nationally-representative sample aged 0 to 14 and 6 to 18 years and reporting overweight plus obesity according to the IOTF criteria, found similar prevalence (25% and 30%). (Australian Bureau of Statistics 2013a; O'Dea 2008) The prevalence of overweight plus obesity was lower (17%) for children of an average age of 5.3 years (range 2.8 to 8.8). (Thurber 2012) A single study found obesity rates were lower when measured according to central obesity criteria compared to IOTF criteria for boys (18% versus 40%, respectively), but not girls (51% vs 50%, respectively). (Valery et al. 2012) A high rate of overweight and obesity was observed in youths in custody. (Haysom et al. 2013)

Two studies reported the persistence of overweight/obesity over time. In LSIC 49.1% (28/57) of the children ≤5 years, who were overweight or obese at wave 3, remained overweight or obese at wave 4 (after approximately one year). For children >5 years, the proportion that remained overweight was 76.4% (68/89). A study conducted in children from public schools in NSW found that 5.4% (41/773) of all children were obese both at baseline and after 2 years.

(Haysom et al. 2009a) The rate of persistent obesity remained at a similar level at 4-year follow-up (5.6%, 45/807). (Haysom et al. 2009b)

Characteristics of overweight / obesity

Gender

Six studies reported prevalence of overweight or obesity by gender. Most are likely to have been underpowered for subgroup comparisons, prohibiting drawing firm conclusions. Four studies, including the nationally based AATSIHS, (Australian Bureau of Statistics 2013a) suggested higher overweight or obesity in girls (from 3.6% higher in AATSIHS to 18.8% higher in a small urban study) (Australian Bureau of Statistics 2013a; Kagawa et al. 2009; Spurrier et al. 2012; Valery et al. 2012), whereas one study showed 2.9% lower obesity among girls (O'Dea 2008) and there were no gender differences in two studies. (Schultz 2012; Sellers, Singh & Sayers 2008)

Age

Eight studies provided estimates of prevalence of overweight or obesity for children of different ages. Overweight plus obesity amongst pre-schoolers varied from 10% to 37% across four studies (Australian Bureau of Statistics 2013a; Australian Government 2013; Thurber 2012; Webster et al. 2013) and was 22.4% in children aged 2-4 years in the ABS AATSIHS. (Australian Bureau of Statistics 2013a) Three studies reported overweight/ obesity rates for children aged 5-17 years including a national 2006 study of Australian school children (O'Dea 2008) (reporting a rate of 21.7%) and two smaller regional studies. (Singh, GR & Hoy 2003; Valery et al. 2012) The ABS AATSIHS, reported a rate of overweight plus obesity for children aged 5-9 of 27.5% and aged 10-14 of 38.5%: a rate of 36.3% in 15-17 year olds was reported separately as a subgroup of adult data. (Australian Bureau of Statistics 2013a)

Remoteness

Three of the four studies offering estimates of the prevalence of obesity/overweight in Indigenous Australians by geographical location found lower rates for children living in more remote areas. (Li, Li & Guthridge 2012; Mackerras et al. 2003; Thurber 2012) (see Table 3) The largest study, LSIC, reported overall rates of overweight plus obesity of 20.8%, 16.4%, 11.0% and 4.8% by level of relative isolation (LORI) of none, low, moderate and high/extremely remote, respectively. (Thurber 2012) The only study that did not display this trend described South Australian children aged 4-5 years and did not report data for the remote population separately. (Spurrier et al. 2012)

Birthweight

A single publication of data from the Aboriginal Birth Cohort demonstrated that at 11 years of age children with intra-uterine growth restriction had a prevalence of overweight of 3.3% compared to 12.9% in children without intra-uterine growth restriction. (Sellers, Singh & Sayers 2008)

DISCUSSION

The review identified and included 21 studies reporting the prevalence of obesity or overweight in Indigenous Australian children of which 12 presented results for one or more sub-groups of interest. The studies are characterised by a high degree of heterogeneity with respect to study design and setting, recruitment method and period, age range

of participants, and measurement of obesity outcomes. The estimate from the most recent and highest quality national level survey data from the 2012-2013 ABS AATSIHS covers children <15 years. (Australian Bureau of Statistics 2013a) This study found that 30.4% of participants were overweight or obese, 19.9% were overweight and 10.5% were obese according to IOTF definitions, which are generally accepted as best practice. A second large national study of children covering a range of ages (6 to 18 years), but recruited through schools, provided a similar estimate of 18.3% overweight and 7.8% obese (26.1% overweight/obese). (O'Dea 2008) These findings indicate that overweight and obesity is a problem in Indigenous Australian children.

The choice of measurement and/or definition of overweight and obesity impacts on the estimate of prevalence of overweight and obesity. (Ruben, 2009) For example, a study conducted in southern Mexico, (Malina et al. 2013) found statistically significant differences in estimates of obesity according to whether the IOTF or the WHO criteria were used. Of the studies included in this review that did not use IOTF, two used percentiles of CDC growth charts - one defined overweight as at the 90th percentile, (Heath & Panaretto 2005) the other as at the 85th percentile. (Webster et al. 2013) Another study reported rates based on WHO growth charts. (Queensland Aboriginal & Islander Health Council 2013) This variation in measurement methods is likely to contribute to the heterogeneity in prevalence estimates observed in this review.

While the ABS AATISHS survey provides the most credible estimate of the prevalence of overweight and obesity in the Indigenous population, the findings were limited by the sampling method which is based upon a census which does not capture individuals living in non-private dwellings (e.g. caravan parks and hostels). A number of other papers included in this review also acknowledged that their population sampling methods did not fully capture Indigenous populations (see Risk of Bias section). (Ferrar & Olds 2010; Thurber 2012) Given the highly mobile nature of the most disadvantaged subgroups within the Indigenous population, the data are unlikely to be representative of these subgroups.

Authors of the LSIC study acknowledged other limitations associated with the conduct of the study. A gradual decrease, across successive waves of the study was observed in the rate of overweight/obesity in children under five years of age from 24% in wave 1 (average age 2.6 years) to 10% in wave 4 (average age 5.3 years). (Thurber 2012) The study report acknowledged that over time improved measuring equipment and “formation of a relationship of trust” between the participating families and the researchers dramatically increased the accuracy of height measurements and decreased the prevalence of missing and implausible data points. The change in rates may represent a learning curve across successive waves of the study from which other cross-sectional studies may not have benefited.

In developed countries, nationally based estimates of the characteristics of weight in Indigenous children are poorly recorded, probably because focusing on a small scattered population subgroup exacerbates an already difficult task. Similar to our study, a review of studies reporting overweight/obesity among North American Indian children demonstrated high prevalence of obesity and overweight with considerable variation across the studies. (Schell & Gallo 2012) As the authors indicated, this may reflect that the Indigenous peoples of North America are “extremely diverse, occupying a wide range of climates and ecological zones”. (Schell & Gallo 2012, p.302) The 2007 New Zealand Health Survey, (Ministry of Health 2012) reporting on a more homogenous Indigenous population, recorded high

levels of obesity/overweight in Maori children. In both countries, prevalence of obesity/overweight was often higher than similar age groups of Australian Indigenous children, for example, see Singh et al, 2010 and Utter et al, 2010. International recognition of the problems associated with the collection of high-quality data led to the establishment of The International Group for Indigenous Health measurement. The group recognised "that the indigenous sample sizes in national surveys are generally too small to enable accurate indigenous rates to be estimated and because of differences in methodology, there should be a cautious approach to International comparisons". (Ruben 2009, p.1289)

While a standard approach to measurement would prove useful when aggregating data, the measure chosen to identify rates of overweight and obesity in Indigenous populations requires careful consideration. BMI, as the chosen measure, may be problematic in Indigenous children, particularly girls, who have a tendency to central adiposity. (Kagawa et al. 2009; Sellers, Singh & Sayers 2008) One study, (Valery et al. 2012) which used both central obesity and BMI (IOTF) measures, found that, although the rates for girls were similar with the two methods, rates for boys decreased significantly if the central obesity measure was used. There is some concern that widely used measures of obesity and cut-off points may not be appropriate for Indigenous populations. (Duncan et al. 2004; Kagawa et al. 2009) In particular, the associations between BMI, percent body fat (%BF), and health risks can vary across different ethnicities and therefore ethnic-specific and country-specific BMI cut-offs for overweight and obesity may be necessary to attain valid prevalence estimates. (Duncan et al. 2004) Taylor et al (2010) argued that since the BMI cut-offs correctly identified insulin resistance and/or metabolic syndrome in people of Polynesian descent there was no need for ethnic specific cut-offs in this group. In contrast, a 2002 study suggests that the risk of diabetes in the adult Aboriginal population increases significantly at a BMI of 22 kg/m^2. (Daniel et al. 2002)

Papers included in this review reported obesity and overweight prevalence for a number of different subgroups including age (Australian Bureau of Statistics 2013a; Australian Government 2013; Nichols et al. 2011; O'Dea 2008; Schultz 2012; Singh, GR & Hoy 2003; Valery et al. 2012), gender (Australian Bureau of Statistics 2013a; Kagawa et al. 2009; O'Dea 2008; Schultz 2012; Sellers, Singh & Sayers 2008; Spurrier et al. 2012; Valery et al. 2012), region (Australian Government 2013; Li, Li & Guthridge 2012; Sellers, Singh & Sayers 2008; Spurrier et al. 2012) and birth weight. (Sellers, Singh & Sayers 2008) Additional factors which have been considered when measuring the prevalence of obesity and overweight for Indigenous children in other countries include the association between obesity or overweight and language spoken at home, degree of physical activity, perceptions of obesity, food consumption as well as the number of hours spent using a computer. (Cooke et al. 2013; Gates et al. 2013; Ghosh 2014)

While the studies included in this review do not allow any firm conclusions, some patterns were identified. For example obesity rates may be higher in females than males although sample sizes in most of the studies are too small to establish a robust estimate of prevalence. (Australian Bureau of Statistics 2013a; Kagawa et al. 2009; O'Dea 2008; Valery et al. 2012) A modelled analysis in the LSIC study found no association between BMI-for-age-Z-score and gender. (Thurber 2012) Rates of obesity may also be higher in school-aged children than pre-schoolers although this may be confounded by the change in cut-off point at the age of 5 years. (Australian Government 2013) In addition, some studies suggested that obesity rates may be lower among children living in remote areas in comparison to urban centres. (Li, Li & Guthridge 2012; Mackerras et al. 2003; Thurber 2012) This finding may be related, at least in part, to

the higher prevalence of low birthweight babies in remote areas. (Singh, GR & Hoy 2003) In addition, a modelled analysis in the LSIC study found that living in an area with low, medium or high remoteness was associated with a significantly lower BMI-for-age-z-score. (Thurber 2012) These findings need to be treated with some caution as they may be confounded by other factors such as differences in socioeconomic status or difficulties in data collection in remote areas.

Limitations of the review

The current review included all studies in which data on the prevalence of overweight/obesity were reported, whether or not this was a primary outcome of the study. This approach aimed to provide an overview of the body of data to determine if there was consistency across studies despite methodologies, or if not, where differences lay. Whilst inclusion of data from studies that did not aim to measure overweight/obesity prevalence may add data with a high risk of bias, the risk of bias was considerable in many studies for which this measure was a primary aim. (For example, see Webster et al. 2013; Wolfenden et al. 2011). Most individual included studies were underpowered for subgroup comparisons but we have presented these data to highlight areas of uncertainty that might be addressed in future research. Meta-analysis was not possible due to the high degree of heterogeneity, in part due to variations in definition of subgroups (apart from gender) and outcome. We note that we did not include analyses in which obesity or BMI was an outcome variable in regression analyses. Such analyses can provide insight into the characteristics of obesity in populations but were considered beyond the scope of the current review. We also note that, although sensitive to the values and ethics in Aboriginal and Torres Strait Islander research and with the involvement of an Aboriginal researcher (DC), we approached this review using primarily western methods of systematic review. The findings may have been different if Indigenous methodologies had been employed

Future research

Methodological shortcomings and gaps in coverage identified in the current review highlight the importance of further research to understand the extent and composition of obesity and overweight in Indigenous Australian children. In particular, studies are needed which measure prevalence of obesity and overweight in sub-groups of Indigenous Australian children and address the concern that many studies miss children living in transitory conditions or non-private dwellings. Such children may represent a subgroup with a prevalence that differs from other Indigenous Australian children. Attention to sensitivity of findings to changes in the measures and cut off points used would be of value.

Conclusion

Variability in study design, conduct and small sample sizes mean that is not possible to derive a single estimate for the prevalence of overweight or obesity in Indigenous Australian children. Even the highest quality studies may not adequately capture obesity/overweight prevalence and characteristics in this population. There is a suggestion that prevalence of obesity is higher in girls, increases as children age, and that children living in remote areas are likely to have lower prevalence than urban living children, but studies vary widely in their estimates and further data, particularly regarding confounding factors, is needed for confirmation.

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CONTRIBUTIONS

JMS, JSG, LGS, CD contributed to design of the review. SMD, JMS, JSG contributed to abstract screening. All authors contributed to study selection, quality appraisal and manuscript preparation. SMD performed data extraction and analysis.

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Figure 1: Study flow diagram

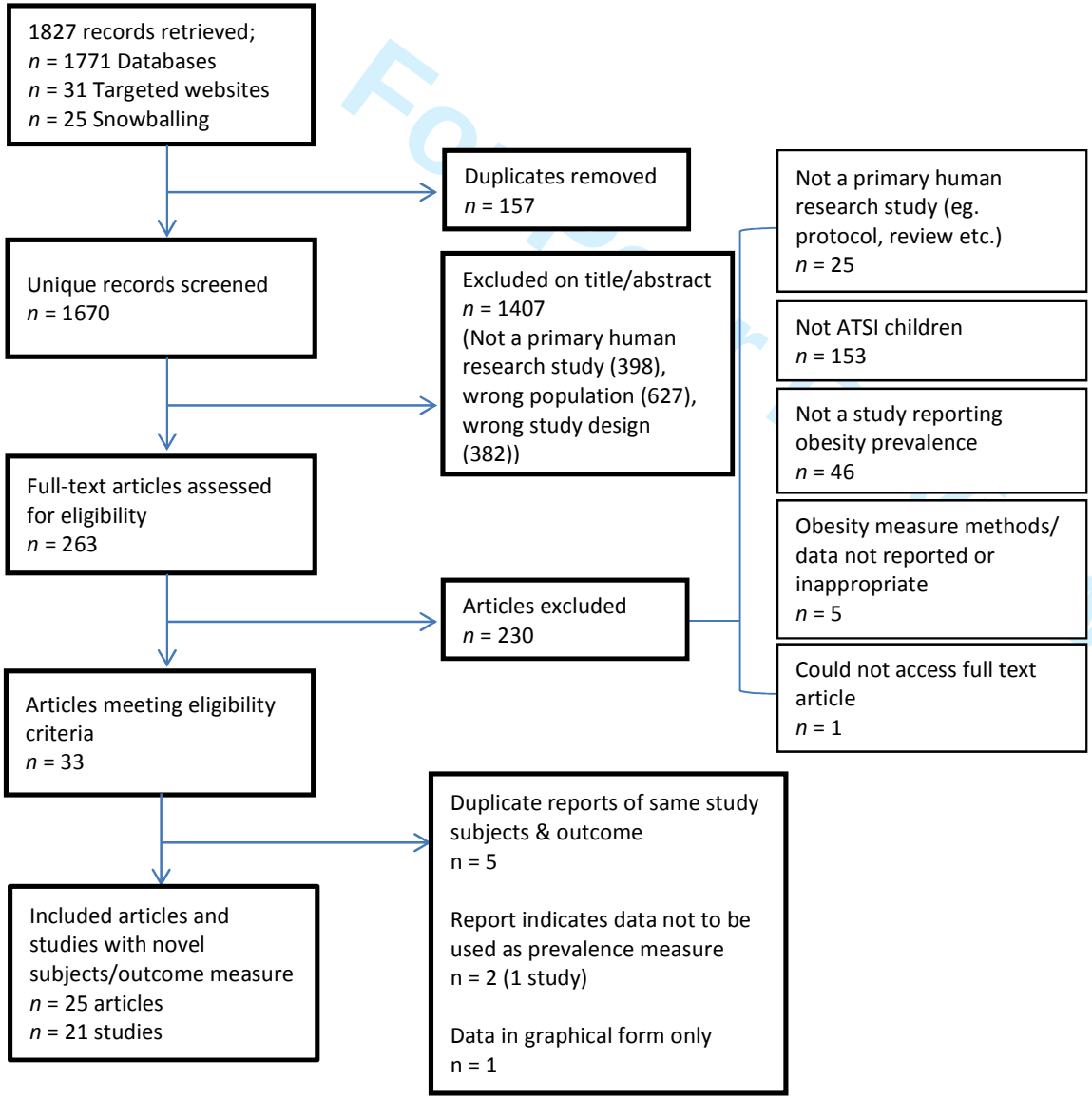

Table 1: Characteristics of included studies

Author and publication date	Setting, design and sample	Study years	Population N (ATSI) Age Gender Remoteness Birthweight	Outcome measurement: method and sub-groups covered
Population-based recruitment				
ABS 2013 (Australian Bureau of Statistics 2013a)	Australia-wide Cross-sectional Sampling based on census housing data	2012- 2013	N = 3835 Age: 0-4 years 31.7%, 5-9 years 27.9%, 10-14 years 25.9% [a] Gender: 51% male Remoteness: major cities 27.2%, inner regional 19.0%, outer regional 19.7%, remote 11.9%, very remote 22.1% Birthweight: NR	IOTF Subgroups: age, gender
Aust Govt 2013 (Australian Government 2013); Thurber 2012 (Thurber 2012)	Australia-wide Cross-sequential with 2 cohorts Purposeful sample: Medicare & Centrelink data	2008- 2009 (wave 1) 2011-2012[b] (wave 4)	N = 1,759 overall, N = 1283 (wave 4) Age: mean (SD) months: 47.1 overall, 31.1 (18.4) wave 1, 41.0 (18.3) wave 2, 52.8 (18.3) wave 3, 64.1 (18.3) wave 4. Gender: male 50.4% (n = 1759) Remoteness: LORI urban 29.7%, low 47.9%, moderate 13.8%, high/extreme 8.6% (for n = 1053) Birthweights: mean 3,296g (SD 623g) (for n = 1,315)	IOTF Subgroups: age, remoteness
Ferrar 2010 (Ferrar & Olds 2010)	Australia-wide Cross-sectional Sample based on random digit dialing	2007	N = 68 Characteristics of ATSI subpopulation NR Study population recruited ages 9-16	IOTF Subgroups: Nil
Singh 2003 (Singh, GR & Hoy 2003)	NT remote coastal Indigenous community Cross-sectional Participants (volunteers) in screening program	1992- 1998	N = 311 Age: mean 13.3 years (12.9–13.7); range 7-17years Gender: NR Remoteness: NR Birthweight: 2.94g (2.9–3.0)	IOTF Subgroups: age
Schultz 2012 (Schultz 2012)	Central Australia Cross-sectional All children invited via direct engagement with community	2010	N = 996 Age: range 5-15 years; 5-9 years 62.5%, 10-15 years 37.5% Gender: 56.9% male Remoteness: NR Birthweight: NR	BMI-for-age ≥+1, ≥+2 SD WHO 2007 growth charts Subgroups: age, gender
Wake 2009 (Wake et al. 2007)	Australia-wide Longitudinal: cross-sequential with 2 cohorts Clustered sampling with stratification from Medicare data	2004	N = 181 Characteristics of ATSI subpopulation NR Population in study ranged 4.3 to 5.3 years.	IOTF Subgroups: Nil

Health-services based recruitment				
Black 2013 (Black et al. 2013)	NSW Retrospective before-and-after study 3 Indigenous community-controlled health services, regular patients invited	2008- 2010	N = 134 Age: Mean 7.6 years (SD 4.2) years, range 2-17 Gender: 47% male Remoteness: NR Birthweight: NR	IOTF Subgroups: Nil
Li 2012 (Li, Li & Guthridge 2012)	NT Cross-sectional Retrospective administrative data from Dept of Health	2011	N = 1059 Age: Recruited children 4-6 years Gender: NR Remoteness: urban 25.4%, remote 74.6% Birthweight: NR	IOTF Subgroups: remoteness
Nichols 2011 (Nichols et al. 2011)	Victoria Cross-sectional Retrospective administrative data from Maternal Child Health centres providing services in 41 local govt areas	1999 - 2007	N = 1138 Age: 2 years 63.3%, 3.5 years 36.6% Gender: NR Remoteness: NR Birthweight: NR	IOTF Subgroups: age
QAIHC (Queensland Aboriginal & Islander Health Council 2013)	Queensland Cross-sectional Regular patients at Aboriginal and Islander Community Controlled Health Services	2010- 2013	N = 2028 Age: 5-14 Gender: NR Remoteness: NR Birthweight: NR	BMI ≥ 95% WHO growth charts[c] Subgroups: Nil
Sellers 2008 (Sellers, Singh & Sayers 2008); Mackerras 2003 (Mackerras et al. 2003); Sayers 2007 (Sayers et al. 2007)	NT, Darwin Cohort Hospital administrative data / births	1998- 2001	N = 482 Age: Mean 11.5yrs (8.8 to 13.8), range 9-14 Gender: 52% male Remoteness: NR Birthweight: 26.2% IUGR, 73.8% non-IUGR	IOTF; ≥85%, >95% 1985 AHFS; ≥85%, ≥95% CDC charts Subgroups: gender, remoteness, birthweight
Webster 2013 (Webster et al. 2013)	Sydney urban fringe Cohort Recruited infants via maternity ward and networks in community	2005- 2007	N = 122 Age: 24 months Gender: 45.1% male Remoteness: NR Birthweight: males mean 3.4kg (SD 0.6), females 3.3kg (0.6)	≥85%, ≥95% CDC charts Subgroups: Nil
School-based recruitment				
Haysom 2009a (Haysom et al. 2009a); Haysom 2009b (Haysom et al. 2009b)	NSW Cohort 37 public primary schools	2002- 2004	N = 773 (2yr) N = 807 (4yr) Age: 4-5.9 years 11.3%, 6-6.9 years 13.6%, 7-7.9 years 15.2%, 8-8.9 years 14.8%, 9-9.9 years 13.5%, 10-10.9 years 13.8%, 11-14.8 years 17.8% Gender: 50.9% male	Obesity ≥2 SD Subgroups: Nil Prevalence persistent obesity @ 2-yr and 4-yr follow-up

			Isolation (ARIA score): least (0-1.1) 25.9%, low-mid (1.2-2.4) 27.2%, high-mid (2.5-4.9) 19.4%, highest (5.0-14.0) 27.5% Birthweight: 412-2920g 29.6%, 2921-3316g 23.1%, 3317-3685g 24.4%, 3686-5272g 22.9%	
Heath 2005 (Heath & Panaretto 2005)	Northern Queensland Cross-sequential 3 primary schools	unclear	N = 72 Characteristics of ATSI subpopulation NR	90-95%, >95% CDC charts Subgroups: Nil
Hickie 2013 (Hickie, Douglas & Ciszek 2013)	ACT, Cross-sectional Retrospective, children enrolled in first year of school	2004- 2008	N = 321 Characteristics of ATSI subpopulation NR Age: Recruited at first year of school	IOTF Subgroups: Nil
Kagawa 2009 (Kagawa et al. 2009)	QLD: Brisbane Cross-sectional Primary & secondary schools	unclear	N = 74 Age: 12.1 ± 0.3 years males, 12.2±0.3 years females, range 9-15 years Gender: 48.6% male Remoteness: NR Birthweight: NR	IOTF Subgroups: gender
O'Dea 2008 (O'Dea 2008)	Australia-wide Cross-sectional 47 randomly selected schools	2006	N = 459 Age: 6-11 years 40.1%, 12-18 years 59.9% Gender: 46.4% male Remoteness: NR Birthweight: NR	IOTF Subgroups: gender, age
Spurrier 2012 (Spurrier et al. 2012)	SA Cross-sectional preschools & kindergartens	2009	N = 337 Age: NR for ATSI subpopulation. Recruited at 4-5 years Gender: 49% male Remoteness: IRSD 928 ± 3.5 (95% CI 921-935) Birthweight: NR	IOTF Subgroups: gender, remoteness
Valery 2012 (Valery et al. 2012)	Torres Strait Cross-sectional 4 Island communities, 5 schools	2003	N = 277 Age: mean 11.2 years mean (SD 3.1), range 5-17 years Gender: 46% male Remoteness: NR Birthweight: NR	IOTF Subgroups: gender, age Central obesity: Jolliffe & Janssen (Jolliffe & Janssen 2007)
Wolfenden 2011 (Wolfenden et al. 2011)	NSW Cross-sectional childcare centres (preschools & long daycare) in Hunter New England region	2007	N = 78 Characteristics of ATSI subpopulation NR Age: Recruited at 2-5 years	IOTF Subgroups: Nil
Population sub-groups				
Haysom 2013 (Haysom et al. 2013)	NSW Cohort 9 custodial centres	2009	N = 151 Age: mean 16.7 years (SD 1.4), range 13-20 years, 84.8% <18 years	IOTF Subgroups: Nil Increased metabolic risk (waist-to-height

			Gender: 86.8% male Remoteness: NR Birthweight: NR	ratio ≥0.5)

Abbreviations: AHFS = Australian health and Fitness Survey; est = estimated; IOTF = International Obesity Task Force; NR = not reported; QAIHC = Queensland Aboriginal and Islander Health Council; SD = standard deviation;

[a] Prevalence rate for ages 15-17 years also reported separately, but not included in the overall prevalence estimate, [b] Estimated from ages of participants at wave 4, [c] significantly overweight

Table 2: Overall prevalence (% n/N) of overweight / obesity in Indigenous Australian children

Author, year	Outcome measure	Prevalence % (n/N)		
		Overweight or obese	Overweight	Obese
Population-based estimates				
ABS 2013	IOTF	30.4%[a] (1226/4033)	19.9%[a] (803/4033)	10.5%[a] (423/4033)
Thurber 2012[c]	IOTF	16.7% (195/1170)	9.6% (112/1170)	7.1% (83/1170)
Ferrar 2010	IOTF	39.7% (27/68)	23.5% (16/68)	16.2% (11/68)
Singh 2003	IOTF	8.9% (27/311)	–	–
Schultz 2012	BMI-for-age ≥+1, ≥+2 SD	26.8% (267/996)	21.4% (213/996)	5.4% (54/996)
Wake 2007	IOTF	28.1% (51/181)	16.8% (30/181)	11.3% (20/181)
Health-services based recruitment				
Black 2013	IOTF	28.3% (38/134)	14.9% (20/134)	13.4% (18/134)
Li 2012	IOTF	7.3% (77/1059)	6.0% (64/1059)	1.2% (13/1059)
Nichols 2011	IOTF	17.8% (202/1138)	13.7% (156/1138)	4.0% (46/1138)
QAIHC 2013	BMI ≥ 95% WHO growth charts	–	–	21%[b] (432/2082)
Sellers 2008	IOTF	11.3% (55/486)	6.4% (31/486)	4.9% (24/486)
Webster 2013	≥85%, ≥95% CDC charts	36.9% (45/122)	14.8% (18/22)	22.1% (27/122)
School-based recruitment				
Haysom 2009b (Haysom et al. 2009b)	Obesity ≥2 SD	–	–	7.4% (82/1248)
Heath 2005	90-95%, >95% CDC charts	18.1% (13/72)	9.7% (7/72)	8.3% (6/72)
Hickie 2013	IOTF	18% (58/321)	12% (39/321)	7% (22/321)
Kagawa 2009	IOTF	54.1% (40/74)	35.1% (26/74)	18.9% (14/74)
Spurrier 2012	IOTF	28% (94/337)	–	–
O'Dea 2008	IOTF	26.1% (120/459)	18.3% (84/459)	7.8% (36/459)
Valery 2012	IOTF	45.8% (127/277)	28% (78/277)	18% (49/277)
Valery 2012	Central obesity	45.8% (127/277)	28% (78/277)	18% (49/277)
Wolfenden 2011	IOTF	24.6 (19/78)	18.8 (15/78)	5.8 (5/78)
Youths in custody				
Haysom 2013	IOTF	43% (65/151)	31.8% (48/151)	11.3% (17/151)

[a] proportion weighted to population benchmarks to account for exclusions & infer results for total in-scope population; [b] described as significantly overweight by authors; [c] wave 4

Abbreviations: BMI = body mass index; CDC = Centers for Disease Control and Prevention; IOTF = International Obesity Task Force; SD = standard deviation; WHO = World Health Organisation

Table 3: Prevalence (%, n/N) of overweight/obesity in Australian Indigenous children by remoteness

Remoteness	Study Author, year	Outcome measure	Prevalence % (n/N)		
			Overweight/ obese	Overweight	Obese
LORI no	Thurber 2012[a]	IOTF	20.8% (65/313)	10.9% (34/313)	9.9% (31/313)
Urban	Li 2012	IOTF	14.4% (39/269)	12.3% (33/269)	2.2% (6/269)
Urban	Mackerras	95%[b]	_	_	15.2% (15/99)
Metropolitan	Spurrier 2012	IOTF	23.8% (40/168)	14.3% (24/168)	9.5% (16/168)
LORI low	Thurber 2012[a]	IOTF	16.4% (83/504)	11.3% (57/504)	5.2% (26/504)
Rural	Spurrier 2012	IOTF	31.5% (53/168)	19.6% (33/168)	11.9% (20/168)
LORI moderate	Thurber 2012[a]	IOTF	11.0% (16/145)	6.2% (9/145)	4.8% (7/145)
LORI high/extreme	Thurber 2012[a]	IOTF	15.4% (14/91)	7.7% (7/91)	7.7% (7/91)
Remote	Li 2012	IOTF	4.8% (38/790)	3.9% (31/790)	0.9% (7/790)
Remote	Mackerras 2003	>95%[b]	-	-	1.2% (4/344)

[a] wave 4; [b] using 1985 Australian Health and Fitness Survey centiles, the authors describe this as "overweight"
Abbreviations: IOTF = International Obesity Task Force; LORI = level of relative isolation

OVERWEIGHT AND OBESITY IN YOUNG INDIGENOUS AUSTRALIANS: A SYSTEMATIC REVIEW. Supplementary Results Tables

Table 1 Prevalence (%) of overweight and obesity in Australian Indigenous children by gender

Gender	Study Author, year	Obesity Outcome	Prevalence (%)		
			Overweight / obese	Overweight	Obese
Male	ABS, 2013	IOTF	28.6 [a]	18.4 [a]	10.3 [a]
	Sellers, 2008	IOTF	11.0	5.1	5.9
	O'Dea, 2008	IOTF	27.7	20.2	7.5
	Kagawa, 2009	IOTF	44.4	30.6%	13.9%
	Valery, 2012	IOTF	40	-	-
	Spurrier	IOTF	25.9	17.5	8.4
	Schultz, 2012	≥+1/+2 SD BMI-for-age	26.4	20.7%	5.8
	Valery, 2012	Central obesity	18	-	-
Female	ABS, 2013	IOTF	32.2 [a]	21.5 [a]	10.7 [a]
	Sellers, 2008	IOTF	11.5	7.7	3.8
	O'Dea, 2008	IOTF	24.8	16.7	8.1
	Kagawa, 2009	IOTF	63.2	39.5	23.7
	Valery, 2012	IOTF	51	-	-
	Spurrier	IOTF	29.8	16.9	12.9
	Schultz, 2012	≥+1/+2 SD BMI-for-age	27.1	22.1	5.1
	Valery, 2012	Central obesity	50	-	-

[a] proportion weighted to population benchmarks to account for exclusions & infer results for total in-scope population

Abbreviations: IOTF – International Obesity Task Force, SD – standard deviation

Table 2 Prevalence (%) of overweight and obesity in Australian Indigenous children by age

Age (years)	Study Author, year	Obesity Outcome	Prevalence (%)		
			Overweight/ obese	Overweight	Obese
Preschool (<5 years)					
2	Nichols 2011	IOTF	17.06	14.42	2.64
2	Webster 2013	85%, 95%[e]	36.9	14.8	22.1
2-4	ABS 2013	IOTF	22.4[a]	15.8[a]	6.5[a]
3.5	Nichols 2011	IOTF	18.94%	12.5	6.47
<5	Thurber 2012	IOTF	9.8	6.3	3.5
Ages >5					
>5	Thurber 2012	IOTF	25.3	13.7	11.6
5-9	ABS 2013	IOTF	27.5[a]	15.4[a]	12.1[a]
5-9	Schultz 2012	+1, +2 SD[f]	23.4	18.1	5.3
6-11	O'Dea 2008	IOTF	21.7	14.1	8.6
5-13[c]	Valery 2012	IOTF	44.8	27	18
7-10	Singh 2003	IOTF	6.5	-	-
10-14	ABS 2013	IOTF	38.5[a]	27.1[a]	11.4[a]
10-15	Schultz 2012	+1, +2 SD[f]	34.4	27.5	6.9
11-17	Singh 2003	IOTF	9.2	-	-
12-18	O'Dea 2008	IOTF	29.1	21.1	8.0
14-18[d]	Valery 2012	IOTF	47.4	30	18
15-17	ABS 2013	IOTF	36.3	20.6	15.8

[a] proportion weighted to population benchmarks to account for exclusions & infer results for total in-scope population; [b] 95% margin of error or proportion; [c] Estimated: Primary school students; [d] Estimated: High school students; [e] centiles of CDC 2000 growth charts; [f] BMI-for-age from WHO growth standards charts

Abbreviations: IOTF – International Obesity Task Force, SD – standard deviation

Table 3 Prevalence (%) of overweight and obesity in Australian Indigenous children by birthweight

Birthweight category	Study Author, year	Overweight, Obesity Thresholds	Prevalence (%)		
			Overweight/ obese	Overweight	Obese
IUGR [a]	Sayers 2007	IOTF	-	3.3	-
Non-IUGR	Sayers 2007	IOTF	-	12.9	-

[a] <10th percentile using Australian-based sex-specific reference curve for birthweight-for-gestational age

Abbreviations: IUGR = intrauterine growth restriction