Schools and Student Obesity:

Research into school-level environmental associations and student weight-related factors

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This thesis is submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy at the University of Oxford

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DECLARATION

This work has not previously been accepted in substance for any degree and is not currently submitted in candidature for any degree.

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ABSTRACT

Background: This thesis investigated the role that primary schools play in promoting healthy eating and physical activity (PA) amongst students. The socio-ecological model (SEM) to health provided the theoretical framework for understanding the different levels of influence on childhood obesity. A systematic review of the evidence was published that looked at the relationship between the school setting and rates of student overweight and obesity (O&O). Its primary aim was to examine if there was a significant association between student Body Mass Index z-scores (zBMI) and the number of school environmental actions in place to promote healthy eating and PA amongst students.

Methods: As part of a larger-scale investigation into childhood obesity led by the World Health Organization (WHO) Collaborating Centre for Childhood Obesity in Victoria, Australia, student- and school-level data were collected using objective measures of student weight outcomes and self-report behavioural questionnaires (providing individual-level data), along with the Be Active Eat Well (BAEW) school environmental questionnaire (providing school-level data). Descriptive and regression analyses were completed to investigate statistical associations between student zBMI and results from the BAEW questionnaire, including once adjusted intermediary factors and clustering.

Results: From a sample of 715 Year 4 and 6 students across 34 primary schools, males reported a significantly higher prevalence of O&O than females (34.3% and 28.7%, respectively) and further analyses were split by gender. Indigenous Australian students reported significantly higher rates of zBMI than non-Indigenous Australians (p-value = 0.001), but with only a small sample size (n = 23). A range of significant associations were found between individual-level factors. Fully adjusted multivariate regression models reported a significant association between student zBMI and the amount that schools did to promote healthy eating amongst female students (p-value = 0.007).

Conclusion: The number of school-level actions in place to promote healthy eating was significantly associated with student zBMI in girls. This thesis was supportive of the hypothesis that schools play an important role in the prevention of childhood O&O. It makes a unique contribution to the evidence-base in terms of the methodology behind the study of school effects on student weight outcomes. It promotes the adoption of a socio-ecological approach to childhood obesity prevention, focused across all levels of society, and provides direction for future research and policy and legislation aimed at preventing childhood obesity in Australia and elsewhere.

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GLOSSARY

Abbreviation	Meaning
ABS	Australian Bureau of Statistics
AHS	2011-12 Australian Health Survey
AMA	American Medical Association
ANGELO	Analysis Grid for Environments Linked to Obesity
BAEW	Be Active Eat Well
BHF CPNP	British Heart Foundation Centre on Population Approaches for Non-Communicable Disease Prevention
zBMI	Body Mass Index z-score
CDC	United States Center for Disease Control and Prevention
CDQ	Children's Dietary Questionnaire
CEIPS	Victorian Centre for Excellence in Intervention and Prevention Science
CUREC	Central University Research Ethics Committee
CVD	Cardiovascular disease
DALYs	Disability-Adjusted Life-Years
DI	Dietary Intake
DNA	Deoxyribonucleic Acid
DoH	Australian Government Department of Health
GWA	Genome-Wide Association
HPS	Health-Promoting School
HTV	Healthy Together Victoria
IYM	'It's Your Move!'
LGA	Local Government Area
LMIC	Low- and Middle-Income Countries
MVPA	Moderate-to-Vigorous Physical Activity
NCDs	Non-Communicable Diseases
NGOs	Non-Government Organisations
NIH	National Institutes of Health
NHMRC	National Health and Medical Research Centre
NPAPH	National Partnership Agreement on Preventative Health
O&O	Overweight and Obesity
PA	Physical Activity
PANAMA	'Physical Activity and Nutrition: Advancing Measurement and Impact Assessment'
PedsQL	Paediatric Quality of Life Inventory
RCT	Randomised Control Trial
ROC	Receiver operating characteristic curves
SHAPES	School Health Action, Planning & Evaluation System
SD	Standard deviation
UK	United Kingdom
US	United States
VO_2	Oxygen consumption
WHO	World Health Organization
WHOCC-CPNP	World Health Organization Collaborating Centre on Population Approaches for Non-Communicable Disease Prevention
WHOCC-OP	World Health Organization Collaborating Centre for Obesity Prevention

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INTRODUCTION

1.1 Childhood obesity: A public health challenge

Childhood obesity is one of the most significant public health challenges of the 21st century. It is caused by an imbalance of calorie intake and calorie expenditure.[1] The prevalence of childhood obesity has risen steadily worldwide over a period of several decades and understanding the root causes has become a policy priority in many countries. National and international guidelines are today mostly focused towards intermediary factors such as unhealthy eating and physical inactivity,[2,3] while it is also widely accepted that the drivers of childhood obesity are complex and found at all levels of society. Many policies targeting children and adolescents have identified schools as the most appropriate setting to promote healthy eating and physical activity (PA).

1.2 Rationale for investigating the impact of schools on childhood obesity

The socio-ecological model (SEM) to health is fundamental to any settings-based approach that aims to improve health.[4,5] It recognises that many of today's public health challenges are too complex to be adequately understood from single-level analyses. Public health researchers and policy-makers alike have begun to look beyond the individual factors that impact upon health, but also the structural influences such as the social, environmental, and economic factors, which comprise the building blocks of the SEM to health. One the most well-known examples of this is the school.

Schools are thought to play a contributing role in the development of childhood overweight and obesity (O&O). Schools are a well-defined setting that have been used as a site to implement an array of student- and school-level interventions designed to influence eating and PA behaviours. The Australian government, for example, has invested in the past decade hundreds of millions of dollars to prevent childhood O&O using school-based interventions. However, it remains unclear if this level of investment can be justified given that the evidence-base is still weak in support of a hypothesis that schools play a meaningful role in the prevention of childhood O&O.[6,7] My thesis aimed to strengthen the evidence-base in this area of research.

1.3 Overall approach and methods of study

My research project was part of a larger-scale investigation into childhood obesity led by the World Health Organization (WHO) Collaborating Centre for Childhood Obesity (WHOCC-OP) in Victoria, Australia. The primary aim of my study was to investigate if there was a significant association between student Body Mass Index z-scores (zBMI) and the amount that schools did to promote healthy eating and PA, and if these associations remained once controlling for various student- and school-level factors and clustering. The methods underpinning my research project sat within the broader aims of the WHOCC-OP's state-wide investigation into childhood obesity, which involved the collection of student height (cm) and weight (kg) for 856 Year 4 and 6 students across 34 primary schools at base-line data collection, coupled with other student-level behavioural questionnaire data and school-level data from the school environmental BAEW questionnaire. At the time of submission, I was not aware of any published studies that had undertaken a similar approach.

My primary research question was:

RQ1. Is there an association between student zBMI and the number of school environmental actions in place to promote healthy eating and PA amongst students, as measured by the Be Active Eat Well (BAEW) questionnaire?

while my subsidiary research questions were:

RQ2. How do researchers characterise the school environment in determining its effect on student obesity? (systematic review)

RQ3. Is there a statistical association between student zBMI and either of the school Food or PA environments?

RQ4. Is there an association between student MVPA, as measured by accelerometery, and the number of school environmental actions in place to promote PA amongst students, as measured by the BAEW questionnaire?

In line with my research questions, my objectives were to:

1. To complete a systematic review of the evidence with respect to how researchers have characterised the school environment in determining its effect on student obesity;

2. To collect valid and reliable data on student zBMI and weight-related factors;
3. To collect valid and reliable school-level data on the promotion of healthy eating and PA in schools; and,
4. To investigate associations between student- and school-level factors.

1.4 Chapter outlines

Chapter Two outlines the public health emergency that is childhood obesity. It describes the situation in Australia and globally, and introduces the concept of healthy eating and PA behaviours with reference to national and WHO guidelines. It discusses the quality of evidence in support of the hypothesis that schools play a significant role in preventing childhood obesity.

Chapter Three presents a systematic review of the evidence which critiqued how researchers have been investigating the impact of school-level factors on student-level rates of O&O.

Chapter Four presents an outline of my research project and describes my roles and responsibilities in the broader context of the WHOCC-OP's cluster-randomised control trial (RCT). I look closely at the validity and reliability of the measurement instruments we used to collect student- and school-level data, as well as the ethical considerations of the research project.

Chapter Five describes the data collection protocols we followed throughout the survey period. It outlines my analytical approach to the data set and breaks down the method I used in constructing my dependent and independent variables.

Chapter Six presents the results from my descriptive analysis. I present a detailed description of the final sample, together with my primary outcome variable, student zBMI, and my secondary outcome variable, student MVPA, as measured by accelerometery. I also describe a range of intermediary factors and my primary exposure variable, as measured by the BAEW questionnaire.

Chapter Seven follows on from my descriptive analysis and investigates further the strength of association between student weight outcomes and the type of school environment. I present a full example of the model building process, followed by an overview of the results from my other regression models using the same approach to model building.

Chapter Eight discusses the key findings from my thesis. It examines my results from the perspective of gender differences, Indigenous Australian disadvantage, and the school-level variations found within the data set. I critique the strengths and limitations of my methods. I present general conclusions and a discussion around the implications of my research in policy, practice, and future research.

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BACKGROUND: Schools and childhood obesity

2.1 Outline of chapter

In this chapter, I describe in detail the causes and outcomes of childhood obesity. I describe the situation globally and in Australia — where my research took place. I discuss the two most significant intermediary behaviours on the pathway to obesity, unhealthy eating and physical inactivity, as well as discuss the role that schools play in promoting these behaviours. I conclude this chapter with a critique of the evidence showing a causal relationship between the type of school environment and rates of childhood O&O — a discussion that flows into the following chapter, which presents a systematic review of the evidence I published on the measurement instruments researchers have used to investigate the strength of this relationship.

2.2 Definition and epidemiology of obesity

Obesity is defined as having an excessive amount of fat accumulation that may impair an individual's health.[8] It is most commonly defined using the Body Mass Index (BMI), with a person being classified as overweight if their BMI is greater than or equal to 25 and classified as obese if greater than or equal to 30. BMI provides the most useful population-level measure of O&O because it is the same for both sexes and for all ages of adults and it only requires two data points: height (cm) and weight (kg).[8] In 2014, the WHO reported that 13% of the world's adult population were obese, with another 39% classified as overweight. Therefore, for the first time in human history, the majority of adults (52%) worldwide were classified as O&O and people of a 'healthy' weight (BMI 20-25) were now strictly a minority group.[8]

Since 1980, the global prevalence of O&O has risen substantially.[9] Once considered a high-income country problem, O&O is today on the rise in low- and middle-income countries (LMICs), particularly in urban settings. In high-income countries, increases in O&O that mostly began in the 1980s appear to have attenuated in the last decade.[9] Conversely, increases in O&O are expected to continue to rise in LMICs, where almost two in three of the world's obese people reside.[9] Because of the major health risks associated with the rise in O&O, it has grown to become a major global health challenge.

In 2010, O&O was estimated to cause 3.4 million deaths worldwide and 3.8% of all disability-adjusted life-years (DALYs).[9] It is now one of the leading contributors to the global burden of chronic disease and disability.[10,11] With increases in BMI, the risk for non-communicable diseases (NCDs) increases. NCDs associated with O&O include cardiovascular diseases (CVD) (chiefly heart disease and stroke) – the leading cause of death globally in 2012 – diabetes, musculoskeletal disorders, and certain cancers.[8] Second only to global climate change, obesity is arguably the most significant public health challenge of the 21st century.[12] The health, societal, environmental, and economic impacts are unprecedented.

Concern about the health risks associated with rising obesity levels has become nearly universal — Member States of the WHO introduced a voluntary target to stop the rise by 2025.[9] To demonstrate obesity's economic impact, 61% of adults in Australia in 2011-12 were classified as O&O and the total annual cost to the Australian economy was an estimated AU$58 billion.[13] With regards to obesity's environmental impact, a study by Edwards and Roberts (2009) showed that a population with an abnormally high mean BMI (40% obesity) required 19% more food energy for maintenance than one with a normal mean BMI (3.5% obesity). The authors in turn found that the maintenance of a healthy population BMI had significant environmental benefits with regards to greenhouse gas emissions.[14]

The primary cause of O&O is an imbalance of calorie intake and calorie expenditure, while the 'causes of the causes' are predominantly a shift in diet to an increased intake of energy-dense foods high in fat and sugars, combined with a reduction in the daily amounts of PA.[1,15,16] The next section discusses the many levels of influence that impact upon a child's eating and activity behaviours.

2.3 Childhood obesity

The age-standardised prevalence of O&O has increased substantially in children and adolescents in LMICs and high-income countries.[9] As LMICs are developing, they appear to follow the same patterns observed in high-income countries. In LMICs, between 1980 and 2013, O&O increased in boys from 8.1% to 12.9% and in girls from 8.4% to 13.4%. In high-income countries over the same period, O&O increased in boys from 16.9% to 23.8% and in girls from 16.2% to 22.6%. Gender differences, according to a systematic analysis by the Global Burden of Disease Study (2014), were insignificant over this period for both LMICs and high-income countries.[9]

Many LMICs are today facing a 'double-burden' of disease. As they continue to struggle with controlling infectious diseases, they are experiencing a rapid increase in O&O.[17] The distribution of childhood nutritional diseases is shifting from a predominance of under-nutrition to a dual burden of under- and over-nutrition.[18] It is not uncommon to find childhood under-nutrition and obesity existing side-by-side, manifest within the same community or even the same household.[17] This double-burden is caused by inadequate pre-natal, infant, and child nutrition, which is then followed by exposure to high-fat, energy-dense, micronutrient-poor foods, and a general lack of PA as the child grows older. This novel and complex issue is challenging governments and public health organisations to tackle opposite ends of the malnutrition spectrum.

Obesity trends are expected to continue to rise worldwide without significant intervention. For a raft of reasons, public health agencies have moved to prioritise strategies that target children and adolescents. It is important to intervene as early on as possible in the development of these unhealthy behaviours — we know from longitudinal studies that childhood obesity is a robust predictor of obesity later in life.[19] Children are also generally more receptive to behaviour change interventions than adults, plus they are far more accessible than adults thanks to schools — thus, it is clear why public health agencies have targeted early childhood in the fight against obesity.[20]

Obesity in children is significantly associated with an increased risk of premature death and disability later in life.[21] According to the WHO, O&O children are more likely to develop an NCD later in life, such as CVD, diabetes and musculoskeletal disorders, and at a younger age than non-O&O children. Recent evidence also suggests that the genesis of Type 2 diabetes and CVD begins in childhood — with childhood obesity serving as the dominant factor.[22] For example, a study by Freedman (2007) found that 70% of obese children had at least one CVD risk factor, with 39% having two or more CVD risk factors.[23] According to the CDC, other physical health risks associated with childhood obesity 'now' – as opposed to later in life – included:[24]

- High blood pressure;
- High cholesterol;
- Increased risk of impaired glucose tolerance and insulin resistance;
- Asthma and breathing problems, such as sleep apnea;
- Joint problems; and,
- Fatty liver disease, gallstones, and gastro-esophageal reflux (i.e. heartburn).

In 2013, the American Medical Association (AMA) labeled obesity as a disease (at any age) "requiring a range of medical interventions to advance obesity treatment and prevention".[25] The AMA's decision went against the advice of its own Public Health and Science Committee, sparking widespread discontent and discussion amongst medical and healthcare communities. The rationale behind the change in classification according to the AMA was to increase the focus on obesity treatment and prevention;[26] however, it did little to highlight the significant social, self-esteem, and emotional wellbeing problems associated with obesity – particularly in children – and some have since argued that the AMA decision did more harm than good in this regard.[27]

We know from quantitative and qualitative research that many obese children are unhappy about their body shape and as a consequence they can develop low self-esteem and self-worth.[28] Low self-esteem and self-worth often impacts upon numerous aspects of a child's health and behaviour, including social adjustment, activity engagement, and goal direction.[28] Low self-esteem has also been linked to depression and suicidal thoughts.[29] For example, a review by Rankin *et al.* (2016) found sex differences in O&O children aged six to 13 years were associated with depression and anxiety.[30] O&O girls included in the review had significantly higher rates of depression than O&O boys, as well as increased odds of developing depression and anxiety with increases in weight. Despite the Global Burden of Disease Study (2014) reporting no gender differences in the prevalence of O&O between 1980 and 2013, the risks and impacts of O&O are certainly different between boys and girls.

During an individual's preadolescent years, self-esteem is believed to be more related to family interactions and support.[29] Family situation and influences are therefore important considerations for any researcher studying the risk factors for childhood O&O and its association with psychological disorders. To illustrate, a study by Kalra *et al.* (2012) found that O&O children often faced ridicule from parents and other family members in the household about their body size and shape.[28] These types of associated emotional problems can often start early in life and O&O children have been shown to be at an increased risk of being victimised or bullied at home and at school. A study by Griffiths *et al.* (2006) reported that childhood obesity was also a predictive factor for bullying involvement, with differences again observed between boys and girls.[31] The study found that preadolescent obese boys and girls were more likely than non-obese children to be victims of bullying — hypothesised to be because they deviated from appearance ideals. In turn, obese boys were more likely to become bullies because of their physical dominance in the peer group.[31]

Finally, poor academic performance is another important consideration which is strongly associated with childhood O&O. However, there is still a paucity of data in this area and studies have found it difficult to ascertain causality (i.e. does childhood obesity cause poor grades, or do poor grades cause childhood obesity — or both). Carey *et al.* (2015) examined a range of educational attainment indicators (school absences, school problems, repeating a grade, and school engagement) against rates of childhood O&O using a sample of 45,255 children and adolescents aged 10-17 years; a data set extracted from the US 2011-12 National Survey for Children's Health.[32] The study showed a significant association between increased weight status and poorer educational outcomes, but it was limited by its cross-sectional study design. Other researchers have criticised these types of studies because they do not use actual grades as outcome measures when assessing academic performance – some studies have implemented their own grading criteria for educational outcomes to overcome this – however, the point is that the evidence-base is poor.[33,37]

The Australian setting

Looking at the situation in Australia – where my research took place – no change in childhood O&O was observed between 1969 and 1985 amongst girls aged 10-15 years (12.2%), but the prevalence of O&O increased by 35% in boys of the same age and over the same period (7.2% to 11.0%).[34] Gender differences were thus a strong predictor of O&O during this time. However, gender differences became less stark as the overall prevalence of O&O rose between 1985 and 2008. The prevalence of O&O among Australian girls aged 10-15 years increased from 12% to 24%, compared to boys of the same age group, who saw an increase from 11% to 26%[35] — this trend was more in line with what was reported by the Global Burden of Disease Study (2014) analysis.[9]

Since the early-2000s, Victoria – the Australian state where my research project was completed – has been a hub for research activities pertaining to childhood obesity prevention (see Figure 2.1). Advocacy groups for obesity prevention and management in Victoria were some of the first to be formed in the country, led chiefly by non-government organisations (NGOs), and academic and professional organisations.[36]

Figure 2.1. Map of the state of Victoria, Australia

In 2008, the Victorian government also commissioned its own study that predicted the prevalence of O&O in children between 2005 to 2025.[36] The authors conducted a multiple linear regression analysis to determine the independent effects of age and year of birth on child BMI.[36] The authors extracted data from eleven cross-sectional national- and state-level population surveys and based their models on previous trends with zero effective interventions. Compared with the O&O prevalence of 21% in both boys and girls aged 5-19 years in 2005, the final models predicted that child BMI would continue to increase in Victoria for both sexes and across the age span, and by 2025 one-third of all 5-19 year olds would be O&O.[36]

In Australia, and worldwide, the obesity picture can appear bleak when assessing the magnitude of this public health challenge. In the next section, I describe what is being done to prevent childhood obesity more broadly, and then specifically in schools — but first I look closer at the causes of childhood O&O, and focus on its two main drivers: unhealthy eating and physical inactivity.

2.3.1 Causes of childhood obesity

The socio-ecological model (SEM) to health, described in more depth in the next section, teaches us to look beyond the individual and to evaluate a multitude of influences.[2,3] A child's environment is complex; it includes areas such as family, peers, school, community, and the society at large — as filtered through media, advertising, and prevailing social norms.[37] Of all the levels of influences on childhood obesity, the home environment is arguably the most significant. The home is where a child spends the majority of their time across the first five years of life — a period which has been shown to cultivate up to 85% of an individual's intellect, personality, and skillset.[38]

The environmental influences on childhood O&O are many and the levels of intervention required to prevent it extends from the child's immediate environment to the larger societal context. Looking at the home environment, however, the critical intervention target is unquestionably the parent(s).[39] Unfortunately, the home environment is also the most difficult part of a child's life to access due to ethical constraints, and more research is regularly called for in this area.[39] We have learned from the available peer-reviewed literature that parents have a powerful influence on their child's eating and activity behaviours, as well as level of body satisfaction.[40] To the extent that weight gain is a function of environment, parents of young children play a crucial role in the development of O&O.

A systematic review by Tzou and Chu (2012) looked at the literature with regards to parental influence and childhood O&O.[41] Reviewing 14 independent studies, the authors used parental control, attitudes, and eating behaviours to determine the parental impact on childhood weight. They concluded that they could not determine the directional analysis of parental control, attitudes, and behaviours and its relationship with child-feeding practices. The authors paid particular attention to the question of whether parental control, attitudes, and behaviours were interrelated or not, as well as their relative importance to each other.[41] They found, however, that in order to assign any causality between parental child-feeding practices and childhood O&O, and unpick the specific determinants, longitudinal studies must be undertaken in this area of research — again, calling for more research into household-based interventions.[41]

Looking beyond the household, there are a number of fixed variables beyond our control. For example, genetics has been one of the biggest factors examined as a cause of obesity. Genome-wide association (GWA) studies have found more than 40 genetic variants associated with BMI and fat distribution,[42] while other studies have reported that BMI is between 25% and 40% heritable.[43] Zhao and Grant (2011), however, argued that this estimation evidence is not necessarily relevant for children.[44] From a review that looked at the genetics of childhood obesity, they found only a few GWA studies had been completed specifically for childhood obesity and that many of the well-established genetic determinants for adult BMI did very little to explain the genetic risk for childhood obesity, suggesting a potential existence of additional loci whose number and effect size remained unknown.[44] Zhao and Grant thus called for further GWA studies specifically for children to identify and fully characterise the function of the genes at these loci in relation to childhood obesity.

In addition to genetics research, epigenetics is an important factor in the aetiology of childhood obesity. Epigenetic marks – or 'imprints' – affect gene expression without actually changing the deoxyribonucleic acid (DNA) sequence.[45] A review by Herrera *et al.* (2011) on the epigenetics of obesity reported that failures in imprinting were strongly associated with a susceptibility to obesity, as well as extreme forms of obesity.[46] The study reported that there is increasing evidence to suggest that certain environmental exposures during critical developmental periods can affect the profile of epigenetic imprints, and result in obesity and other disorders later in life.[46]

Finally, another potentially important "fixed" determinant of weight status – at any age – is basal metabolic rate, or 'metabolism'. Human metabolism is the main component of daily energy expenditure and accounts for 60-70% of total energy expenditure in the majority of people;[47] however, older adults (>70 years) have lower basal metabolic rates than younger adults by as much as 20-30%.[48] It has been hypothesised that obese individuals have lower overall basal metabolic rates.[47] However, few metabolism studies have looked specifically at childhood obesity and a review by Sahoo *et al.* (2015) on the causes of childhood obesity concluded that differences in metabolism were unlikely to be responsible in any large part for the rise in childhood O&O over the last few decades.[49]

Without discounting the many influences on childhood obesity, or their complexity, the two most important drivers must still reside in unhealthy eating and physical inactivity — which I discuss in more depth in the following two sections. I breakdown what it means for a child to eat 'healthy' and to be 'active', as well as provide examples specific to the Australian setting.

2.3.1.1 Causes of childhood obesity: Unhealthy eating

For the majority of human history, food has been scarce and life-threatening stressors frequent.[49] Food scarcity constituted a major threat to human survival, and eating behaviours and child-feeding practices evolved in response to this threat.[50] Elevated glucocorticoids and depressed insulin levels served adaptive purposes.[50] However, in today's obesogenic (obese-promoting) environment, where palatable, inexpensive, ready-to-eat foods are readily available, humans are eating far beyond metabolic need.

What constitutes a 'healthy diet' can often be hotly-debated and politicised.[51] Today, international bodies such as the WHO promote a balanced diet that contains a significant amount of fruits and vegetables, and foods which are low in fat (especially saturated fats), salt, and sugar.[52] The WHO considers a healthy diet as one that gives the body the vital nutrients it needs in order to function properly.[52] The WHO warns that a diet high in fats and salts, and low in fruits and vegetables, increases a child's risk of NCDs later in life, as well as lower overall quality-of-life and premature death.[52] An important component of eating healthily is fruit and vegetables, which, if consumed daily in sufficient amounts, can help to prevent NCDs — such as CVD, certain cancers, Type 2 diabetes, and depression.[53] Low fruit and vegetable intake, however, has been estimated to cause approximately 31% of ischaemic heart disease and 11% of strokes worldwide.[53]

According to Scaglioni *et al.* (2011), food preferences are the product of an interplay between genetic and environmental factors, and that the innate mechanisms which regulate appetite are modified by experience.[54] Or to paraphrase Bray (2004), "The genetic background loads the gun — but the environment pulls the trigger".[55] Scaglioni *et al.* analysed evidence from twins studies for a strong genetic influence on appetite traits amongst children and adults. The authors concluded that even among fruit and vegetables, which are all relatively low in energy, children prefer fruit and vegetables that deliver the most calories per gram.[54] Thus, if a child is surrounded by an energy-dense, high-fat food environment, they hypothesised that it is in their very nature – or that they were 'hardwired' – to consume such food types. Longitudinal studies have also shown that once these instinctive dietary behaviours are acquired during childhood, they tend to persist through to adulthood, which gives more weight to focusing on early childhood.[56]

Childhood obesity is a form a malnutrition.[57] It has been well-publicised that a major determinant are sugary-sweetened beverages – or 'soft drinks' – in a child's diet, which have increased considerably over the last few decades. Research shows a clear association between soft drink consumption and a range of poor health outcomes, such as Type 2 diabetes, metabolic syndrome, tooth decay, body weight, and lower intakes of milk, calcium, and other nutrients.[58] In 2010, Malik *et al.* published a random-effects meta-analysis that pooled together eleven studies and compared sugary-sweetened beverage consumption in the highest and lowest quantiles in relation to Type 2 diabetes risk.[59] Using data from these eleven studies, which included 310,819 participants of all ages and 15,043 cases of Type 2 diabetes, the authors found that individuals in the highest quantile of soft drink consumption had a 26% higher risk of developing Type 2 diabetes than those in the lowest quantile.[59] However, these findings were limited by a cross-sectional study design.

Food promotion has a direct effect on a child's nutrition knowledge, preferences, purchase behaviour, consumption patterns, and diet-related health.[60] As children are amongst society's most vulnerable, they should be protected from forces who seek to profit from the promotion of unhealthy behaviours. In 2012, Cairns *et al.* published a systematic review on different marketing practices that targeted children.[60] A total of 99 primary studies and 16 review articles met the inclusion criteria for questions related to the nature and extent of food promotion to children. The authors reported that current marketing practices predominantly promoted low-nutrition foods and beverages. They illustrated a clear gap in the literature on how substantive policy implementation can be achieved in this area, and the authors recommended that future studies include a greater emphasis on translational work.

<u>The Australian Dietary Guidelines</u>

Governments worldwide have invested considerable resources into developing their own national guidelines which aimed to educate various groups about what constitutes a healthy diet. In line with WHO recommendations, the Australian Government Department of Health (DoH) promotes a diet high in fruit and vegetables and low in fat, salt, and sugar.[2,61] The guidelines recognised fruit and vegetable intake as important components of a healthy diet across all ages. A nutritious, balanced diet is particularly important for children due to the high nutrient requirements during this period of growth and development.[62] The Australian Government National Health and Medical Research Council (NHMRC) has also promoted a high consumption of fruit and vegetables amongst children aged 5-14 years, which they have said reduces the risk of weight gain and NCDs later in life.[63]

The Australian Government DoH has recommended that children and adults eat a wide variety of nutritious foods and at least five servings of fruit and two servings of vegetables daily, and slightly less for children.[61] In the 2011-12 Australian Health Survey (AHS), only

30% of children aged 5-14 years met the "Australian Dietary Guidelines for Children and Adolescents 2003" for the daily consumption of fruits and vegetables.[64,65] It is important to note that the 2003 dietary guidelines were revised in 2013 and that the most recent guidelines recommended a higher intake of fruits and vegetables — so the proportion of children in 2011-12 AHS meeting national dietary guidelines would have actually been even less. To explain, the 2003 guidelines for daily fruit and vegetable intake recommended that children and adolescents consumed:[65]

1) For children aged 4-7 years: 1 serve of fruit and 2 serves of vegetables;
2) For children aged 8-11 years: 1 serve of fruit and 3 serves of vegetables; and,
3) For children aged 12-17 years: 3 serves of fruit and 4 serves of vegetables.

A single serve of fruit included one apple, two apricots, or one cup of chopped fruit. One serve of vegetables included one medium potato, one cup of salad vegetables, or half a cup of cooked vegetables.

The revised 2013 dietary guidelines recommended the following:[65]

1) For children aged 4-8 years: 1 ½ serves of fruit and 4 ½ serves of vegetables;
2) For children aged 9-11 years: 2 serves of fruit and 5 serves of vegetables; and,
3) For children aged 12-18 years: 2 serves of fruit and 5 ½ (boys) and five (girls) serves of vegetables.

Key findings from the 2011-12 AHS reported no significant gender differences in fruit and vegetable consumption (30% met national guidelines).[61] Furthermore, there was no significant difference in fruit and vegetable consumption between children living in areas of greatest disadvantage and least disadvantage, and no significant differences between children of a healthy weight and those that were O&O. Of the variables that were significantly associated with dietary behaviours, younger children aged 5-9 years were more likely to meet the Australian dietary guidelines (2003) than older children (aged 10-14 years) (44% compared with 15%).[64] The 2011-12 AHS reported that children living in urban areas were also less likely to meet the Australian dietary guidelines (2003) than children living in regional and remote parts of the country (26% and 38%, respectively).[64]

A well-known at-risk group in Australia is its Indigenous population. Indigenous Australians represent 3.0% (669,000) of the total Australian population. They are at an increased risk for a range of poor health outcomes, including childhood O&O.[66,67] In total, only 7% of Indigenous Australian children and adolescents aged 5-17 years met the revised Australian dietary guidelines (2013) — well below what was reported in the 2011-12 AHS for non-Indigenous children and adolescents (30%). An independent study was conducted by the Australian Bureau of Statistics (ABS) for Indigenous Australian children and adolescents after the change in guidelines for the recommended daily servings of fruit and vegetables, so Indigenous Australian children and adolescents were able to be evaluated using the revised Australian dietary guidelines (2013).

2.3.1.2 Causes of childhood obesity: Physical inactivity

PA is the major determinant of energy expenditure and it is fundamental to maintaining a healthy energy balance. It is well-established that regular exercise reduces the risk of heart disease, Type 2 diabetes, hypertension, colon cancer, breast cancer, and depression.[3] It is beneficial at all stages during a child's formative years, and active play is important in terms of their physical, psychological, and social growth and development.[68] According to the WHO, physical inactivity has increased in prevalence to the point where it has become the fourth highest risk factor for mortality across all age groups, accounting for 6% of all deaths globally — and it follows high blood pressure (13%), tobacco use (9%), and high blood glucose (6%) as the leading causes of worldwide mortality.[3]

For children, it is important that they regularly engage in some form of exercise as it is a strong predictor of their PA behaviours later in life.[69] The many changes to the PA environment over the last fifty or so years can help to explain the increases in physical inactivity. People in high-income countries have witnessed a substantial shift in lifestyle, urban environments, and transportation systems. Active transport, for example, has significantly declined in recent decades in countries such as the United States (US), United Kingdom (UK), and Australia, as car travel grew to become the predominant form of personal mobility.[70] The health impacts of this type of change on child health can be demonstrated by Davison *et al.* (2008), whom published a study showing how children who actively commuted to school had higher levels of PA, as well as improved cardiovascular fitness, compared with children who did not.[71]

The evidence-base shows us that obese children are generally less active than non-obese children.[72] They spend more time in sedentary pursuits, such as watching television and using other electronic media, and this increase in screen-time is linked to a range of poor health outcomes, including obesity and other NCDs.[73] In 2011, Tremblay *et al.* published a systematic review that looked at the relationship between sedentary behaviour and multiple health outcomes for children and adolescents aged 5-17 years.[74] A total of 232 peer-reviewed studies, including 983,840 participants, met the selection criteria. Television watching was the most common measure of sedentary behaviour, and body composition the most common outcome measure. According to Tremblay *et al.*, daily television viewing for more than two hours was significantly associated with decreased fitness, unfavourable body composition, lowered scores of self-esteem, and poor academic outcomes.[74] This finding was supported by Grontved and Hu's (2011) meta-analysis on television viewing, which also showed a strong association with increased risk of Type 2 diabetes, CVD, and all-cause mortality — across all age groups.[75]

Children who are less active are generally less healthy;[76] however, effective strategies to improve childhood PA behaviours are not as recognisable. In 2011, Craggs *et al.* published a systematic review that illustrated the limited success of PA promotion interventions that target youth.[76] Their study synthesised the peer-reviewed evidence regarding the determinants of change in PA for children (4-13 years) and adolescents (14-18 years). From the 46 included studies, Craggs *et al.* found large heterogeneity in study samples, exposure variables, and outcome variables.[76] Thirty-one of the included studies had also relied entirely on self-report PA data, which has been shown to be an unreliable measure of PA behaviour in children;[77] the latter finding highlights the need for more research to better inform the development and targeting of PA interventions, as well as the need to focus more on objective measures of PA behaviour.

Accelerometery is one such objective measure of PA behaviour. An accelerometer is a battery-powered device that measures proper acceleration, often worn on an individual's wrist or hip.[78] The ability to measure PA behaviour more accurately is useful not only for better understanding the association between PA and certain health outcomes, but also for monitoring secular trends in behaviour and evaluating the effectiveness of different interventions and programmes.[79] There are many reasons, however, why researchers continue to collect self-report PA behaviour data. Accelerometers are generally much more expensive and more burdensome on study participants, together with a general lack of agreement amongst researchers about where the count-specific cut-points should lie for different intensities of activity, which has therefore restricted study comparison.[80]

An important finding from population-level accelerometery studies is the observed difference in the prevalence of PA behaviours compared to self-report measures. In large population-level studies that rely on self-report measures, the error associated with recall techniques is estimated to be between 35% and 50%, with varying error rates depending on age group and disease condition.[80] Accelerometery, however, helps to reduce this error rate and to explain in large part the heterogeneity in study outcomes. More research is needed in this area, but the consensus appears to be that accelerometery-driven research is the way forward to achieve more valid and reliable PA behaviour assessment.[79,80]

<u>The Australian PA Guidelines</u>

Physical inactivity has major implications for the general health of children, and in response to its increase in prevalence the WHO in 2010 called on its Member States to develop and implement their own national guidelines. Responding to the WHO's call to action and a shift in focus to intervening at an earlier age, the Australian Government updated its national PA guidelines for children and adolescents. In 2014, the Australian Government DoH released the 'Make *Your* Move – Sit Less – Be Active for Life!' report, which was designed to improve PA and sedentary behaviours across all ages (except for guidelines aimed at children aged 0-5 years, which was released immediately following the WHO's call to action).[81,82]

The 2014 guidelines defined PA as any activity which gets an individual:

1) Moving;
2) Making their breathing become quicker; and/ or,
3) Making their heart beat faster.

In contrast, it defined sedentary behaviour as when a person was sitting or lying down — excluding time spent asleep.[80]

The Australian Government DoH originally only released updated national PA guidelines for children aged 0-5 years, a report titled: 'Move and Play Every Day'.[82] It wasn't until four years later that the Australian Government DoH released the 'Make *Your* Move – Sit Less – Be Active for Life!' guidelines. These updated PA guidelines (2014) separated recommendations for individuals aged 5-12 years, 13-17 years, and 18+ years; they followed on from a systematic review of the evidence done by a panel of leading Australian PA researchers in 2012-13.[83]

The expert panel's review assessed the relationship between PA and the biopsychosocial indicators of health and healthy development in children and adolescents aged 5-18 years. It ultimately recommended to the Australian Government DoH that PA in children aged

5-12 years occur in as many ways and often as possible — they reported that greater amounts of PA was associated with a variety of health benefits for children. However, the authors also concluded that the evidence-base was still not strong enough for specific vigorous-intensity, dose-based recommendations for PA in childhood, and they recommended that more research be done in this area.[83]

The PA guidelines (2014) recommended that children aged 5-12 years do at least 60 minutes of MVPA daily, and no more than two hours of screen-time for entertainment per day.[81] The Australian Government DoH's definition of 'moderate' intensity activities included those that required "some effort", but the child was still able to speak easily while engaging in these activities — examples given included fast walking and riding a bike or scooter. 'Vigorous' activities required more effort and made the child breathe harder and quicker — examples given included running, and playing soccer or netball.[81]

The 2011-12 AHS reported that 23% of Australian children aged 5-14 years met national PA recommendations every day — referencing the previous national PA guidelines (2008).[84] Approximately half of the children surveyed met the national PA recommendations (2008) on five-to-six days (32%) or three-to-four days (22%) per week. No significant difference was found between boys and girls (24% and 22%, respectively), which is similar to what was reported for dietary behaviours.[64] Age difference, however, emerged again as a significant factor, with younger children aged 5-9 years twice as likely than older children (10–14 years) to meet the national PA guidelines (2008) across the week (32% and 15%, respectively).[64]

No significant difference was observed in the level of PA for children living in areas of greatest disadvantage and least disadvantage, nor between children of a healthy weight and those that were O&O.[64] This last finding was in part surprising given that the proportion of healthy weight children who met the national PA guidelines (2008) was observably higher than children who were O&O (23% compared with 19%).[64] Children living in urban areas were less likely to meet national PA guidelines (2008) in comparison to those living in regional and remote areas (20% and 30%, respectively), while almost one-in-two Indigenous Australian children aged 5-17 years (no data was available specific to Indigenous children aged 5-12 years) met the national recommendations for PA, compared to one-in-three for non-Indigenous Australian children (48% and 35%, respectively).[64]

Summary

Unhealthy eating and physical inactivity are complex behaviours. Governments worldwide have significantly increased their investments in research and programmes to better understand them. Today, most national and international guidelines focus on these two intermediary factors, but it is also becoming increasingly accepted that the drivers of obesity are complex and found at all levels of society. Many governments now look beyond just the individual-level factors that impact upon childhood obesity, but also the structural influences, such as the social, environmental and economic factors — which comprise the building blocks of the SEM to health.[4]

2.4 The socio-ecological model to health

The SEM to health recognises that many of today's public health challenges are too complex to be adequately understood with single-level analyses. It is fundamental to any settings-based approach – such as within a school – that aims to improve health outcomes in a defined population. It recognises that the social determinants of health are at its foundation and it integrates multiple levels of influence to impact on health behaviour, while emphasising the interaction between factors within and across all levels of the health behaviour. To illustrate, Townsend and Foster (2013) proposed that two key concepts underpinned the SEM to health approach when studying the association of unhealthy eating amongst students in schools, which are 1) Behaviour affects and is affected by multiple levels of influence, and 2) Individual behaviour shapes and is shaped by the social environment.[85] The authors concluded after applying this approach to a sample of 6,693 students aged 11-16 years across 64 Welsh secondary schools that the greatest amounts of variance could be explained by student interpersonal factors, which highlighted the importance of social influences on student choices.[85]

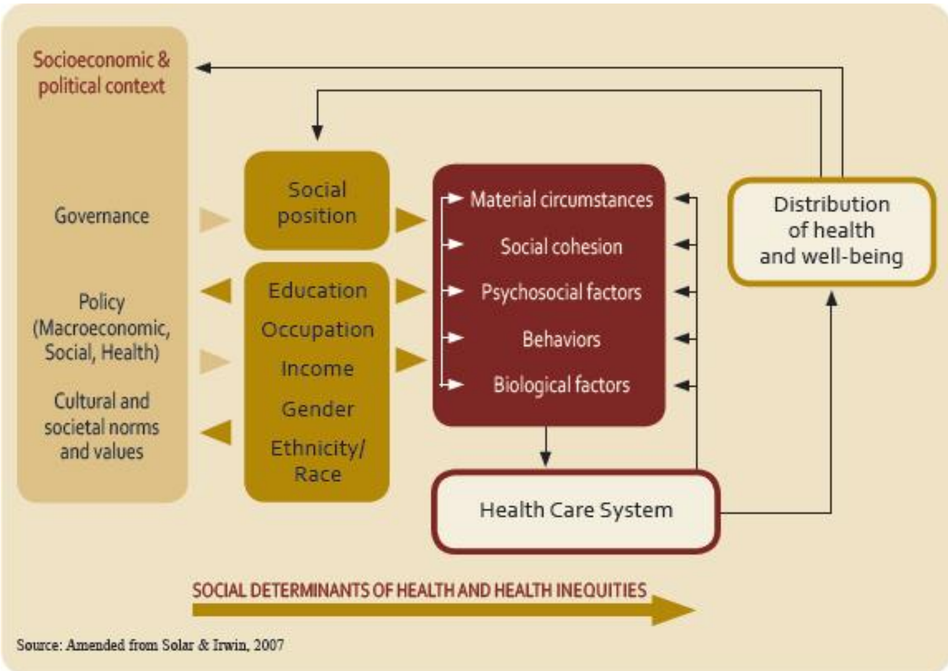


Figure 2.2. The WHO Social Determinants of Health Conceptual Framework [86]

The development of the SEM to health led the WHO to establishing its own Commission on the Social Determinants of Health (CSDH), which was designed to support Member

States and its global health partners to better address the social factors leading to poor health and health inequalities.[86] The conceptual framework presented in Figure 2.2 was developed by the CSDH with the intention to describe the relationships among individual and structural variables on the pathway to different health outcomes. The CSDH was ultimately disbanded in 2008, but not before it drew the attention of governments and general society worldwide towards the social determinants of health — in the hope of creating better social conditions for health, particularly among society's most vulnerable.

In developing the Social Determinants of Health Conceptual Framework, the CSDH followed three guiding principles:

1. Improve the conditions of daily life — the circumstances in which people are born, grow, live, work, and age;
2. Tackle the inequitable distribution of power, money, and resources – the structural drivers of those conditions on daily life – globally, nationally, and locally; and,
3. Measure the problem, evaluate action, expand the knowledge base, develop a workforce that is trained in the social determinants of health, and raise public awareness about the social determinants of health.[86]

The third principle is particularly relevant to the research project undertaken in my thesis. The SEM to health teaches us to point policy-makers towards a need to create environmental conditions that support and promote effective and sustainable behaviour change. The CSDH's three principles, together with its conceptual framework in Figure 2.2, was created to show the complexities and significant challenges faced in trying to influence population health. Moreover, it highlights the interactions between people within their physical and socio-cultural environments, calling upon the individual to no longer be viewed in isolation from larger social units — which is vital when dealing with a complex public health issue such as childhood obesity.

Looking specifically at obesity, the US Centers for Disease Control and Prevention (CDC) has developed its own model, which frames the SEM to health in a slightly different way to the CSDH (see Figure 2.3).[87] The CDC model includes five levels of influence and all levels must be taken into consideration in developing obesity prevention strategies. The CDC effectively describes the factors which influence health as at the individual, interpersonal, organisational, community, and systems levels.[87]

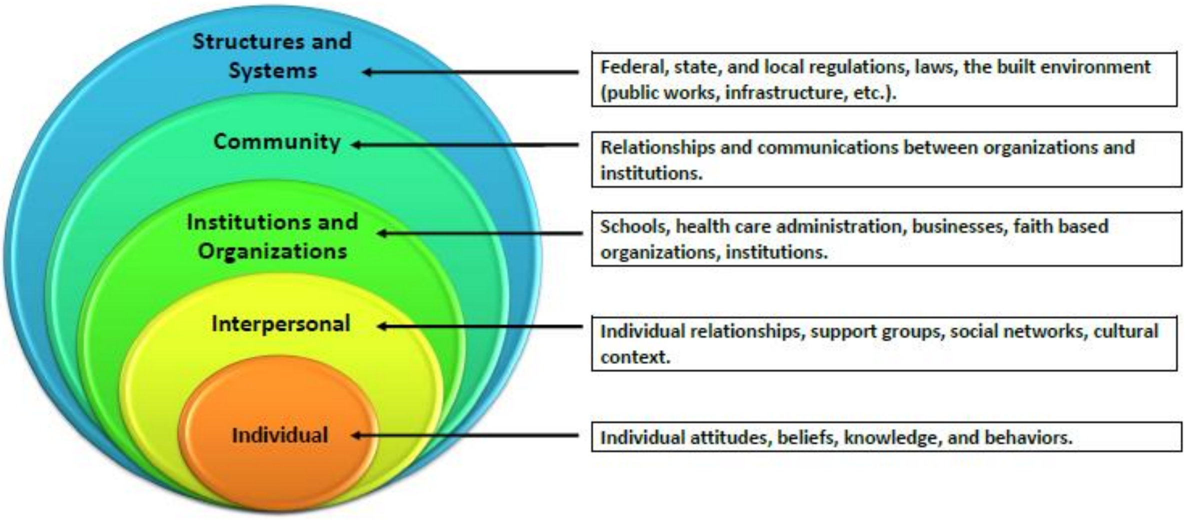


Figure 2.3. Different levels of the US CDC Social Ecological Model in relation to obesity [87]

In 2011, Brown wrote a doctoral thesis on the CDC framework to determine the efficacy and quality of interventions targeting childhood O&O. [88] Brown evaluated the effectiveness of two independent US studies (one at the micro-level and one at the macro-level) with an emphasis on childhood O&O. The first study reviewed the 'Trim Kids' programme, an intervention with applications at the individual, interpersonal, and organisational levels. The second study evaluated the health education curricula of ten US states against rates of childhood O&O.[88] Brown found that if the CDC's five-level SEM to health was to move from a theoretical model to a proven strategy for preventing childhood O&O, much more research was still needed in needed in this area. Little else has been published with reference to the CDC model.

The SEM to health in essence is complex. It will always be difficult to separate contextual and compositional factors, and to unpick the determinants of obesity at the level in which they are transacting. In the next section, I introduce what has been done to prevent childhood obesity at the highest level through the WHO, before looking closely at one of the most commonly-used prevention sites in all of NCDs research: schools.

2.5 Prevention of childhood obesity in schools

The WHO recognises population-based prevention as being vital to addressing the rising levels of obesity and other NCDs, and it divides population-level approaches into three broad components.[89] The first component focuses on the structures within governments that are designed to support childhood obesity prevention policies and interventions, which include:

- Leadership;
- Dedicated funding for health promotion;
- NCD monitoring systems;
- Workforce capacity; and,

- The networks and partnerships that need to be in place in order to support and enhance the effectiveness of the more direct policy initiatives and community-based interventions.

The second component is population-wide policies and structures, which are direct policy actions that help to create environments supportive of healthy eating and PA behaviours.[89] These types of policy instruments include laws and regulations, taxes and subsidies, and public health and social marketing campaigns. The third and final component is community-based interventions. The interventions and programmes at this level are manifold and applied across many settings. Evidence suggests that they are often strengthened when they include a high degree of community engagement at all stages of their development, so that they incorporate local information and integrate well with existing infrastructures.[89] The types of different settings commonly targeted in this third component include early childcare settings, healthcare facilities, and schools.

In 1995, the WHO announced its 'Global School Health Initiative' (GSHI). The GSHI was designed to increase the number of schools around the world adopting their 'Health Promoting Schools' (HPS) strategy,[90] which was designed to move policy away from implementing programmes that targeted specific health aspects and onto those that captured a more holistic approach towards health promotion.[91] This was viewed at the time as a significant step forward for the school system.[90]

The WHO defines 'health promotion' as the process of enabling people to increase control over and to improve their health, which aligned with the Ottawa Charter for Health Promotion's (1986) foremost definition:[92]

"Health promotion is the process of enabling people to increase control over, and to improve, their health. To reach a state of complete physical, mental and social well-being, an individual or group must be able to identify and to realize aspirations, to satisfy needs, and to change or cope with the environment. Health is, therefore, seen as a resource for everyday life, not the objective of living. Health is a positive concept emphasizing social and personal resources, as well as physical capacities. Therefore, health promotion is not just the responsibility of the health sector, but goes beyond healthy life-styles to well-being."

-- WHO, Ottawa Charter for Health Promotion (1986)[92]

Before Member States adopted the HPS approach, the bulk of obesity research was still focused on the individual; up until the 1990s a significant number of these studies focused solely on genetic causes.[93] The HPS approach took into account the many isolated influences on child and adolescent health and it aimed to better understand how they interacted. The process of health promotion in this context was continual — akin to the SEM to health, the HPS strategy moved away from a focus on individual behaviours and towards a network of social and environmental interventions.

Health promotion has since evolved to become part of a wider public health movement, playing an important role in public health policy and helping to tackle major public health issues like obesity.[91] The HPS approach shifts the emphasis of health promotion onto 'healthier settings' — and due to their relative convenience and accessibility, schools quickly became the preferred setting for many governments worldwide to implement health promotion strategies that targeted unhealthy eating and physical inactivity in childhood.[94,95,96,97]

The school setting is an environment that has been hypothesised to influence student health by means of both compositional (which people are found in a place) and contextual factors (the characteristics of a place).[98] It still remains unclear, however, how much impact schools have on childhood weight status. This is in large part because it is very difficult to capture an environment's influence on human behaviour — even in one so well-defined as schools. The upshot is that schools should be a healthy place for children to be and to learn, regardless of whether or not they have any impact on rates of obesity.

It is difficult to know if such enormous investments by governments around the world into school-based interventions can be justified, or shown to be cost-effective. In Australia, the Federal Government in the last decade had invested hundreds of millions of dollars into school-based programmes designed to promote healthy eating and PA behaviours amongst students in the hope to prevent childhood obesity. The Howard government, for example, spent more than AU$200 million in the mid-2000s on the 'Active After School' programme; evaluation studies have since shown this programme to be fully ineffective.[99] More recently, the Turnbull government spent in 2015 AU$160 million on their "Sporting Schools Initiative" — a programme that aimed to increase the participation rates in sport in primary schools, particularly in female students.[100] No evaluation was published at the time of submission of this thesis, but the point remains that despite a weak evidence-base, successive Australian governments have been willing to spend big on school-based interventions — and the critics have started to line up in recent years.

Swinburn and Wood (2013), for example, criticised the Federal Government for caving to State Government pressure and rushing through 'soft' interventions that were more politically digestible — as opposed to the policies recommended on multiple occasions by the National Obesity Taskforce.[101]

The National Obesity Taskforce is led by the Australian Health Ministers Advisory Council, Chairpersons from leading private and non-government health agencies, and scientific experts. As the most influential organisation in Australia in terms of the strategic direction for obesity-relevant policy, the National Obesity Taskforce is underpinned by five broad goals with respect to children.[102] Although broad, the Taskforce's five goals embody the SEM to health, hoping to allow policy-makers the flexibility they need to respond effectively and in line with the latest research. These five goals are:

1. To achieve healthier weight in children and young people through actions which first stop and then reverse the increasing rates of O&O;
2. To increase the proportion of children and young people who participate in and maintain healthy eating and adequate PA;
3. To strengthen children, young people, families and communities with the knowledge, skills, responsibility and resources to achieve optimal weight through healthy eating and active living;
4. To address the broader social and environmental determinants of poor nutrition and sedentary lifestyles; and,
5. To focus action on giving children, young people and families the best possible chance to maintain healthy weight through their everyday contacts and settings.

It is hoped that the growing frustration by the research community, and relevant organisations, enough pressure will be applied to policy-makers to take obesity prevention and management more seriously — because the 'low-hanging' options are no longer so digestible.[99,100] The next section critiques a systematic review of the evidence by the Cochrane Collaboration on interventions intended to prevent childhood obesity.

Effectiveness of childhood obesity interventions

A Cochrane systematic review of the evidence for interventions is generally considered one of the highest-quality evidence reviews.[103] On several occasions a Cochrane review has examined the effectiveness of interventions for preventing childhood obesity.[39,104,105] The majority of studies included in their 2011 review on childhood obesity interventions were school-based (78%), which in turn made it the most comprehensive review of the evidence on school-based interventions designed to prevent childhood obesity to date, after publishing two reviews previously on the same subject.[39,104,105]

The authors of the Cochrane review restricted their criteria to include controlled studies, with or without randomisation, and studies were excluded if they had less than twelve-weeks follow-up. Most of the included studies targeted children aged 6-12 years. In total, 55 studies with children aged 0-18 years were included in their narrative synthesis, with grouped outcome measures being adiposity, PA, and diet-related behaviours. A total of 27,946 children were included and their results were split into three age groups: 0-5 years, 6-12 years, and 13-18 years. The review also included a meta-analysis using 37 of the 55 intervention studies.

Across the three age groups, intervention effects were reported as -0.26kg/m^2 for children aged 0-5 years (95% CI: -0.53 to 0.00, I^2=85%). Intervention effects for children aged 6-12 years were reported as -0.15kg/m^2 (95% CI: -23 to -0.08, I^2=79%) and this age group comprised the bulk of studies included in the meta-analysis (73%). Finally, intervention effects were -0.09kg/m^2 in adolescents aged 13 to 18 years (95% CI: -0.20 to 0.03, I^2=71%).[39]

Interestingly, despite a high level of overall observed heterogeneity among study outcomes (I^2 = 82%), the authors concluded that these programmes were effective in reducing childhood obesity. An *I*-squared statistic of 82% infers a very high level of observed heterogeneity, or variation, amongst study outcomes between each study. This indicates that caution should be taken when interpreting the results in this review. For comparison, a lower *I*-squared statistic (I^2 = 74%) was reported in a different Cochrane review by Richards *et al.* (2013),[106] and the authors of the latter review – on face-to-face interventions that promoted PA behaviours – concluded that they were unable to draw any reliable conclusions because of the significant heterogeneity found amongst the observed effects (i.e. their *I*-squared statistic was considered to be too high).[106] The 2011 Cochrane review also made note that in the studies that reported successful outcomes against childhood obesity the authors found a high degree of uncertainty about the levels at which these interventions were effective (the individual- or the school-level), which cast further doubt around the quality of the evidence included in this review.[39]

A total of 78% of the studies included in the Cochrane review were school-based, so the authors conducted a meta-analysis specifically for just the school-based interventions and for children aged 6-12 years. This meta-analysis, however, had no significant impact on the sample effect size (-0.17kg/m^2; 95% CI: -0.25 to -0.09; *p*-value = 0.001), and although the authors did not report the degree of heterogeneity amongst study outcomes that they found, they reported that it was not reduced (i.e. the I^2 statistic was not lower than 82%).[39] Similar to the first meta-analysis, caution should be taken when interpreting these results.

Overall, this Cochrane review provided valuable insight into the effectiveness of school-based interventions aiming to reduce childhood obesity — it was by far the most comprehensive review done. It was limited, however, by a controlled study design and it included studies ranging from single exposures to single outcomes to multi-level, which restricted study comparison. The authors were unable to distinguish between the range of programme components in each study, which made it difficult to determine the precise source of any observed changes in weight status (i.e. was the effect due to individual- or school-level factors). In summary, the review synthesised the evidence to the highest standard, but it was limited due to the poor quality evidence available. The conclusions offered by the authors were also limited because they did not review the validity and reliability of the measurement instruments that were used by the researchers when collecting the school-level data included in the evaluated school-based interventions. In seeing this gap in the literature, I set about to complete a systematic review on the subject and the results are presented in the next chapter.

2.6 Summary of chapter

Since 1980, the global prevalence of O&O has risen substantially and it is estimated today to kill 3.4 million people annually.[9] This trend is expected to continue to rise without intervention. Governments worldwide have prioritised strategies that target children, as behaviours learned in childhood are strongly predictive of adult behaviours.[23] Genetics research was the dominant theme in the 1980s, but improving dietary and PA behaviours has since become the cornerstone of childhood obesity prevention and management. Researchers and policy-makers now aspire to look beyond the individual-level drivers of obesity and to address its many layers of influence. It is clear that it is very difficult for an individual to be healthy in an environment that promotes unhealthy behaviours.[107] The WHO in turn has encouraged its Member States to adopt the SEM to health in the development of obesity prevention frameworks that target children. It is crucial that research strives to unpick the determinants of obesity at the level in which they are transacting so that they can be better managed. It still remains unclear, however, how much impact various settings are having on childhood dietary and PA choices — and the school setting in particular has some way to go in this regard. I aimed to contribute in part to improving the quality of research being done in this area in the following chapter.

- 3 -

BACKGROUND: How have researchers characterised the school environment in determining its effect on student weight status? A systematic review of the literature

3.1 Outline of chapter

In this chapter, I present a systematic review of the literature with respect to how researchers have characterised the school environment in determining its effect on student weight status. As shown in the previous chapter, there is a paucity of evidence showing a link between the school environment and student weight outcomes – and researchers have continued to call for more research to be done in this area. My aim was to critique the quality of measurement instruments that researchers have been using. A full account of this study was published in BMC Obesity (see Appendix One).[108]

3.2 Rationale for systematic review

As discussed in Chapter Two, systematic reviews of the evidence regarding the school effect on student weight status continue to call for more evidence in order to draw reliable conclusions.[39,109,110] However, the evidence-base cannot be improved until there is clarity first on how researchers are actually measuring this relationship between schools and students.

The process of validating a research instrument is in large part focused on reducing the error in the measurement process. A review by Kimberlin and Winterstein (2008) highlighted the common issues related to the validity and reliability of measurement instruments in population health research, which are the two key indicators for the quality of a measurement instrument.[111] The validity is the extent to which interpretations of the results of a test are warranted, while the reliability estimates evaluate the stability of measures, the internal consistency, and the interrater reliability of instrument scores.[111] Kimberlin and Winterstein found that the most common issues associated with measurement instruments were the accuracy of data collected, particularly amongst studies involving self-report and secondary data sources, and the use of data to answer different research questions (i.e. not what the data were originally collected for).[111]

The aim of this review was to critically assess the methods used by researchers to characterise the school environment in examining its effect on childhood weight status. I wanted to improve the quality and consistency of research being done. Prior to this review, it was unclear how the research community were investigating the school's impact on student O&O. Many studies were either isolating certain parts of the school environment or attempting to capture multiple components simultaneously. Different features of the school environment may be having greater influence on student weight status than others; certain combinations may also be consequential. It was critically important to understand the different interactions and to provide clarity on the quality of measurement instruments being used in this space, so that researchers can have confidence in their findings moving forward.

3.2.1 *Search strategy*

The following sections describe the systematic approach I used. My research question was:

1. How have researchers characterised the school environment in determining its effect on childhood weight status?

The "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) statement was followed throughout the reporting of this review.[112] The PRISMA statement comprised a 27-item checklist and I followed the five-phase flow diagram shown in Figure 3.1.

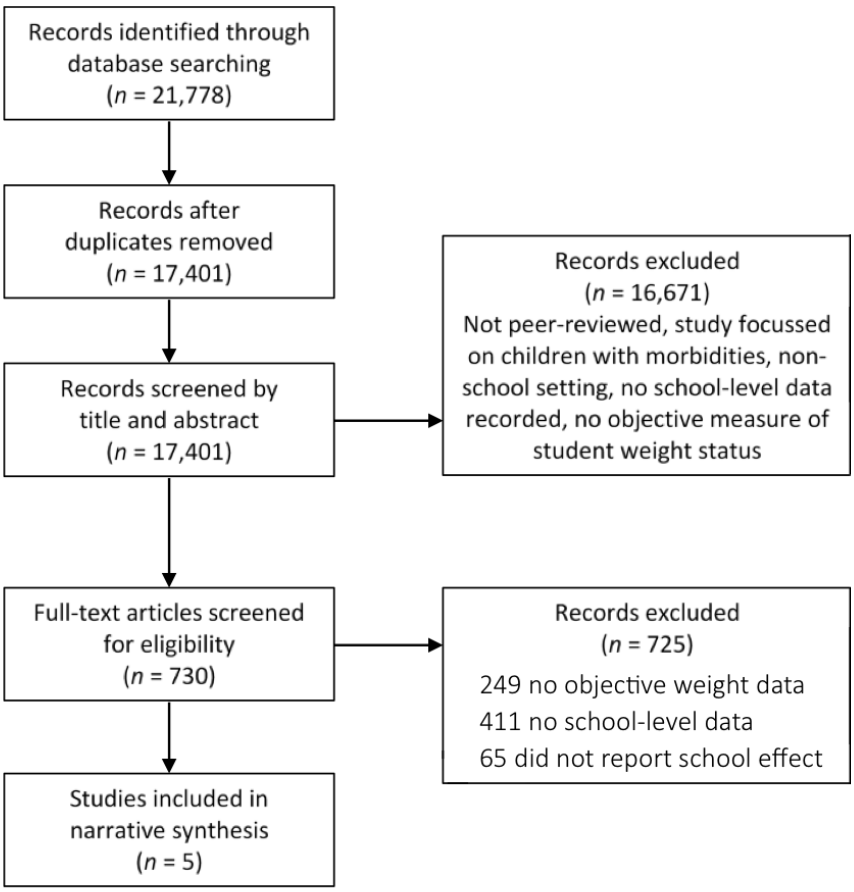


Figure 3.1. Search strategy based on PRISMA statement

My review protocol and questions were registered prior to analysis on the International Prospective Register of Systematic Reviews (PROSPERO) (Registration No. CRD42014008829). No ethics approval was sought for this review as no primary data collection took place.

Sensitive search statements were used — the search statement included all relevant publications up to 31 January 2014. Terms were combined using Boolean operators OR (within rows) and AND (between rows). MeSH (Medical Subject Heading) terms were used (or equivalent thesauri) in conjunction with Free-Text terms. Final search terms were as follows:

Table 3.1. Search statement for systematic search in MEDLINE Complete using EBSCOhost platform

Search Item	**Search Terms**
Schools	*MeSH:* Schools+ *FT:* school* OR school environment OR health?promoting school OR healthy?school OR whole?school
AND	
Students	*MeSH:* Child+ OR Students+ *FT:* child* OR adolescen* OR student* OR pupil* OR school?children OR youth OR teen*
AND	
Weight Status	*MeSH:* Obesity+ OR Overweight+ *FT:* obes* OR overweight OR body mass index OR BMI OR adiposity OR per?cent body fat OR skin?fold thickness OR abdominal obesity OR central adiposity OR waist circumference

MeSH = Medical Subject Heading; *FT* = Free-text; + = Exploded search; * = Truncation; ? = Wildcard

In Table 3.1, the 'Schools' search item was searched independently by: Abstract (AB), Word in Major Subject Heading (MJ), Word in Subject Heading (MW), Exact Major Subject Heading (MM), Exact Subject Heading (MH), Subjects (SU), and Title (TI). This was to avoid a search returning publications that included the Author details (e.g. E. Plugge – *School* of Public Health). The number of publications exported into Endnote X6 was 10,195.

Table 3.2. Search statement for systematic search using EMBASE database

Search Item	Search Terms
Schools	*EMB:* Schools+
AND	
Students	*EMB:* Students+ *FT:* pupil* OR 'school?children'
AND	
Weight Status	*EMB:* Obesity+ *FT:* obes* OR overweight OR 'body mass index' OR BMI OR adiposity OR 'per?cent body fat' OR 'skin?fold thickness' OR 'abdominal obesity' OR 'central adiposity' OR 'waist circumference'

EMB = EMBASE Subject Heading; + = Exploded search; *FT* = Free-text

This search used the EMBASE database and the total number of publications exported into Endnote X6 was 3,302.

Table 3.3. Search statement for systematic search using CENTRAL database

Search Item	Search Terms
Schools	*MeSH:* Schools+ *FT:* school* OR school environment OR health?promoting school OR healthy?school OR whole?school
AND	
Students	*MeSH:* Child+ OR Students+ *FT:* child* OR adolescen* OR student* OR pupil* OR school?children OR youth OR teen*
AND	
Weight Status	*MeSH:* Obesity+ OR Overweight+ *FT:* obes* OR overweight OR body mass index OR BMI OR adiposity OR per?cent body fat OR skin?fold thickness OR abdominal obesity OR central adiposity OR waist circumference

MeSH = Medical Terms; + = Exploded search; *FT* = Free-text

This search was limited to control trials. No systematic reviews were included. The total number of publications exported into Endnote X6 was 875.

Table 3.4. Search statement for systematic search in CINAHL Complete using EBSCOhost platform

Search Item	Search Terms
Schools	*CINAHL:* Schools+ *FT:* school* OR school environment OR health?promoting school OR healthy?school OR whole?school
AND	
Students	*CINAHL:* Child+ OR Students, Elementary OR Students, Middle School OR Students, High School *FT:* child* OR adolescen* OR student* OR pupil* OR school?children OR youth OR teen*
AND	
Weight Status	*CINAHL:* Obesity+ *FT:* obes* OR overweight OR body mass index OR BMI OR adiposity OR per?cent body fat OR skin?fold thickness OR abdominal obesity OR central adiposity OR waist circumference

CINAHL = CINAHL Subject Heading; + = Exploded search; *FT* = Free-text; * = Truncation; ? = Wildcard

The total number of CINAHL publications exported into Endnote X6 was 4,491.

Table 3.5. Search statement for systematic search in PsycINFO using EBSCOhost platform

Search Item	Search Terms
Schools	*THES:* School Environment OR School Based Intervention *FT:* school* OR school environment OR health?promoting school OR healthy?school OR whole?school
AND	
Students	*THES:* Students OR Elementary School Students OR High School Students OR Junior High School Students *FT:* child* OR adolescen* OR student* OR pupil* OR school?children OR youth OR teen*
AND	
Weight Status	*THES:* Obesity OR Overweight *FT:* obes* OR overweight OR body mass index OR BMI OR adiposity OR per?cent body fat OR skin?fold thickness OR abdominal obesity OR central adiposity OR waist circumference

THES = 'Thesaurus' PsycINFO Subject Heading; + = Exploded search; *FT* = Free-text

The total number of PsycINFO publications exported into Endnote X6 was 2,745. Using the above search statement, a total of 21,768 publications were exported into Endnote X6. A preliminary search for duplicates records reported a total of 4,387. The total number of publications left before screening by title and abstract was 17,401.

PICOS statement

The PICOS statement is presented in Table 3.6. The statement refers to Population, Intervention / Exposure, Comparator, Outcome and Study Design. This structured approach helps researchers to frame basic search statements, but as seen below the entire PICOS statement is not always used.

Table 3.6. PEOS statement for systematic review

Population	Exposure	Outcome	Study Design
Students aged 4-12 years	At least one primary school-level measure of the environment	At least one objective weight- or adiposity-related variable	Observational; case control; RCT

I included data from empirical school-based controlled trials (with or without randomisation) and observational studies. Study design and implementation were reported, while studies must have been designed, or had an underlying intention, to prevent obesity, or measure the association between the primary school environment and student weight status. Controlled studies were categorised into long-term (12 months or more) and short-term (under 12 months), which referred to the length of the intervention itself, or to a combination of the intervention with a follow-up phase.

My review focused on the students in schools — by school, I meant educational institutions for students aged 4-12 years (including sixth form). If any studies followed student outcomes from before age 13 and to beyond age twelve, I also included these with declaration.

A commonly used research framework to help categorise different environmental components, particularly in schools, is the Analysis Grid for Environments Linked to Obesity (ANGELO) framework.[113] It is a conceptual model that aims to help researchers better understand the 'obesogenicity' (measure of obese-promotion) of different environments, with a school recognised as a micro-environment. The ANGELO framework breaks down an environment into four key pillars: the economic (what are the costs), physical (what is available), political (what are the rules) and socio-cultural (what are the attitudes and beliefs) elements.[113] This framework was chosen because it was useful in categorising the different environmental elements; the school-level measures were grouped according to whether they related most to the physical, policy, economic, or socio-cultural environments. If there was uncertainty about categorisation, my primary supervisor, Dr. Plugge, and I would meet to discuss the study under consideration and present our reasoning. Although this never transpired, we would have presented our case to a third reviewer (my secondary supervisor, Assoc. Professor Foster) if we could not come to an agreement, and he would make the final decision.

Dr. Plugge and I initially categorised studies according to the target age group and included those with children that were aged less than 13 years at the commencement of the study. We excluded studies designed for children with a critical illness or severe co-morbidities. Studies with interventions that included children who were already obese were also included; this reflected the public health approach that recognises the prevalence of a range of weight within the general population of children. We also included studies of interventions or programmes that involved diet and nutrition, exercise and PA, lifestyle and social support. Reference lists of studies and review articles were then traced, while no restriction was placed on who delivered the intervention or investigated the school-to-student relationship. The inclusion and exclusion criteria are presented in Table 3.7.

Table 3.7. Inclusion and exclusion criteria in line with PEOS statement

	Inclusion criteria	Exclusion criteria
P	Primary school students (4-12 years) Male and Female	Not about school students Study only included adolescents or adults (over 12 yrs) or children aged 3 years or under Children with conditions and morbidities affecting growth Animal study Study was targeted to critically-ill children or children with severe co-morbidities
E	At least one school-level parameter in relation to student weight status	Not concerned with the school site No school-level parameters recorded School-level measurement was not researched in relation to student weight status
O	At least one objective and quantitative measurement of weight status	Not about weight status No objective measurement of obesity No quantitative measurement of obesity
S	Primary school environment was researched in relation to childhood obesity independent of intervention	Study only reported school-to-student relationship with respect to the intervention

Empirical correlation and comparative research were included, which must have captured at least one school-level measure of the environment and at least one objective weight- or adiposity-related student variable. Once I removed duplicates, I first excluded studies by Title. This significantly reduced the number of studies that were reviewed by Abstract. Studies were divided into three groups in Endnote X6 by: 1) Definite, 2) Possible, and 3) Immaterial. Inclusion criteria are outlined in Table 3.8.

Table 3.8. Data extraction form for title and abstract screening

	Criteria	Tick if yes
1	Concept: Includes objective student weight outcomes	◻
2	Concept: Influence of the school environment	◻
3	Concept: Focus of the study is on the school-to-student relationship	◻
4	Primary Empirical Study (regardless of study design)	◻
5	English	◻
6	Peer reviewed	◻
IF YES to all above criteria, include study (circle):		**YES** or **NO**

3.3 Full-text screening and narrative synthesis

Once the Titles and Abstracts were screened, all remaining articles (730) were reviewed by Full Text. Thereafter, a data extraction form was used for each publication to inform the narrative synthesis, collating and summarising the results from each study. To assist our analysis and transparency, we then used the ANGELO framework to categorise the school-level evidence. A total of five articles met the inclusion criteria and were included in our narrative synthesis.[114,115,116,117,118]

3.4 Quality assessment

Numerous tools exist to assess methodological quality, or risk of bias in systematic reviews; however, few have undergone extensive reliability or validity testing. Our review was not restricted to any particular study design, but we considered the Newcastle-Ottawa Scale (NOS) quality assessment (QA) tool the most suitable for assessing the quality of each article because the five included studies were observational and the NOS was developed for this particular study design.[119] According to Hartling *et al.* (2012), who published a critique on the validity and inter-rater reliability for a range of QA tools, the developers of the NOS tool were shown to have previously examined its face and criterion validity, inter-rater reliability, and evaluator burden.[120] The face validity was evaluated as strong by comparing each individual assessment item to their stem question. The NOS's criterion validity had strong agreement with the Downs and Black QA tool, based on a series of ten cohort studies evaluating hormone replacement therapy in breast cancer, with an intra-class correlation (ICC) of 0.88.[120] Hartling *et al.* also found that the inter-rater reliability for NOS on observational studies was high, with an ICC of 0.94. Evaluator burden, however, as assessed by the time required to complete the NOS, was reported to be significantly less than the Downs and Black tool (p-value = 0.001).[120]

The NOS implements a 'star system' to judge study quality based on three broad perspectives: the selection of the study groups, the comparability of the groups, and the ascertainment of either the exposure or outcome of interest.[119] For the purposes of our review, we only included the QA items relevant to cross-sectional studies (the full NOS also included questions relevant to case-control studies, but these questions were removed). The NOS 'star system' for observational studies provides a score on a 9-point scale ranging from a highest-quality paper (score = 9) to lowest quality (score = 1) (see Table 3.9). Each criterion receives a single star if appropriate methods have been reported. The specific quality items aimed to assess: (i) the selection criteria and representativeness of study participants (score up to 2 stars); (ii) comparability of study design and analysis (3 stars); (iii) the exposure measure (2 stars); and (iv) the outcome measure (2 stars).

Table 3.9. Newcastle-Ottawa Scale (NOS) Quality Assessment star rating system

SELECTION		***STARS***	***COMMENTS***
Characteristics of students included in study clearly defined	Cohort studies: inclusion/ exclusion criteria given ***** Case control: case definition given ***** No description		
Representativeness of the study participants	Yes representative ***** Potential for selection bias No description given		
Total stars allocated for selection (max 2)			
COMPARABILITY (cont.)			
Comparability of cases + controls or cohorts on the basis of the design or analysis	Study controls for socio-economic status ***** Study controls for other potential confounding factors e.g. ethnicity ***** No controls undertaken or no adjustments attempted		
Non-response rate	Non-respondents described ***** Rate different / no designation		
Total starts allocated for comparability (max 3)			

EXPOSURE			
Ascertainment of exposure	Secure record * Structured interview (blinded to case/ control status) * Objectively measured * Interview not blinded Written self-report No description		
Same method of ascertainment for exposure	Yes * No		
Total stars allocated for exposure (max 2)			
OUTCOME			
Were the main obesity outcome measures used accurate (valid and reliable)	Yes * No		
Assessment of outcome (overweight/ obesity)	Objectively measured assessment (e.g. BMI) * Record linkage (e.g. database records) * Self-report No description		
Total stars allocated for outcome (max 2)			
Additional comments			
Total Score	/ 9		

3.5 Results

A systematic search of the literature identified 21,778 potential articles to answer the research question, including 4,377 duplicates (see Figure 3.1). We found 730 articles that met all criteria as a result of Title and Abstract screening. Of these, 725 did not meet the inclusion criteria, with the vast majority of articles focused only on intermediary factors (e.g. PA levels, dietary intake), or they were without any objective measure of student adiposity, or they did not report school-level data. Of note, 65 of the 725 articles were excluded from the narrative synthesis despite having the data required to analyse the effect of school-level factors on student weight status. These articles, however, were focused on either the differences between cases and controls and/or the effect of the specific intervention being trialed; authors had thus chosen not to report on the relationship between environmental factors and student obesity, which could have been done at baseline.

All five studies included were cross-sectional (Table 3.10).[114,115,116,117,118] Four of the five studies were conducted in North America and the other in the UK. All were based within the primary/ elementary school setting as defined by the authors. Two studies were focused on Year 5 students and the other three presented results for combined year levels. We found studies had investigated a wide range of school-level factors in relation to its effect on student weight status. Studies were focused on either the food or activity environment, with one investigating both intermediaries.

Table 3.10. Summary of study characteristics

Study/ Location	Study design/ sample	Outcome of interest	*Exposure measure used* Method of data collection	Validity/ reliability	ANGELO framework	School exposure measure and reported association(s) with student weight outcome (95% CI) (^ = p-value less than 0.05)	QA
Veugelers & Fitzgerald, 2005 [114]/ Canada	Cross-sectional/ 5,200 Yr 5 students from 228 schools	Body Mass Index (BMI)	A written survey was completed by the school principal on the presence of healthy menu alternatives.	Not reported	A Policy-related factor was researched (1)	1. *School provided healthy menu alternatives:* Overweight = OR 0.91 (0.77, 1.09) Obesity = OR 0.85 (0.63, 1.15)	3
Fox *et al.* 2009 [115]/ US	Cross-sectional/ 2,228 Yr 1-12 students from 287 schools	BMI (*obesity* only)	A written survey was completed by a foodservice manager about the frequency and type of foods made available in the cafeteria.	Not reported	Policy (2-6)	2. *Low-nutrient, energy-dense foods available* = OR 1.09 (0.57 – 2.08)^ 3. *Whole or 2% milk offered* = OR 1.17 (0.75 – 1.82)^ 4. *Fresh fruit/ raw vegetables not offered daily* = OR 1.13 (0.73 – 1.75)^ 5. *French fries/ similar products offered regularly* = OR 2.70 (1.58 – 4.62)^ 6. *Dessert offered more than once per week* = OR 1.78 (1.13 – 2.80)^	6
Harrison *et al.* 2011 [116]/ UK	Cross-sectional/ 1,725 Yr 5 students from 92 schools	Fat Mass Index (FMI)	A written survey was completed by a 'head teacher' about school policies. A 'trained assessor' completed an audit of school grounds. Local council provided general information.	Not reported	Physical (7) Policy (8-11) Economic (12)	7. *Lower FMI was found in girls attending schools with more pupils in their age group*^ (interquartile analysis) 8. *Better cycle support was associated with higher FMI in girls*^ (interquartile analysis) 9. *Higher FMI was associated with boys who were allowed to eat any foods at break-time*^ (interquartile analysis) **Insignificant findings not reported for:** 10. *Food-related learning* 11. *UK Govt 'healthy school programme'* 12. *Free school meals*.	5
Rundle *et al.* 2012 [117]/ US	Cross-sectional/ 624,204 K-12 students from 1,276 schools	BMI	Data were extracted from the New York City Department of Education enrolment database.	Not reported	Economic (13) & Socio-cultural (14)	13. *Students received free or reduced-price lunches:* Overweight = OR 1.05 (1.00, 1.08)^ and Obesity = OR 1.13 (1.10, 1.18)^ **Insignificant findings not reported for:** 14. *Ethnicity of students in school*.	5

Leatherdale 2013 [118]/ Canada	Cross-sectional/ 2,331 Yr 1-4 students from 30 schools	BMI (*over-weight* only)	A written survey was completed by the 'senior administrator most knowledgeable about school policies and practices.' A school built environment survey was completed by a 'trained assessor' using the 'Environmental Points of Interest' tool.	Not reported	Physical (15-16) Policy (17-21) Socio-cultural (22-25)	15. *Moderate level of student access to a variety of facilities on and off school grounds during school hours* = OR 0.39 (0.16, 0.92)^ 16. *Good level of student access to a variety of facilities on and off school grounds during school hours* = OR 0.32 (0.12, 0.86)^ **Insignificant findings not reported for:** 17. *PA used as reward* 18. *Good PA transport to and from school* 19. *Good implementation of daily PA* 20. *Good amount of daily PA* 21. *Good training of PA teachers* 22. *Good consistency of intramural PA* 23. *Good incorporation of PA into other subjects* 24. *Good community feedback on school PA* 25. *Good PA promotion by teachers*	1

^ Results were reported as statistically significant (p-value less than 0.05)

Using the NOS tool, we found much variation in the quality of each study, ranging from scores of one to six out of a possible nine (see Appendix Two for full copies of NOS results). According to the NOS's QA criteria, none of the included studies were found to be strong; three were moderate and two were poor (see Table 3.11).

Table 3.11. Quality assessment results

Study	Selection criteria/ representativeness of participants (out of 2)	Comparability of study design & analysis (out of 3)	Exposure measure (out of 2)	Outcome measure (out of 2)	Total
Veugelers & Fitzgerald	0	1	1	1	**3**
Fox *et al.*	2	1	1	2	**6**
Harrison *et al.*	1	1	1	2	**5**
Rundle *et al.*	0	1	2	2	**5**
Leatherdale	0	0	0	1	**1**

The application of the ANGELO framework greatly assisted in our analysis of school-level factors, which were grouped into one of four environmental elements: physical, policy, economic, and socio-cultural. The presence of policy-related elements was most common among studies with one school-level factor related to policy implementation. Socio-cultural elements of the school environment were the second most common school-level factor, while a small amount investigated the physical and economic elements within the school setting.

Studies reported a variety of food- and activity-related factors that were significantly associated with student weight status. These findings, however, represented only a small proportion of the number and variety of school-level factors investigated. Fox *et al.*, for example, reported the availability of French fries and desserts in the school cafeteria as associated with obesity among primary school students.[115] Harrison *et al.* also reported lower FMI rates in girls attending schools with more pupils in their age group, whereas higher FMI was associated with higher cycle provision amongst girls.[116] Boys were reported to have a higher FMI if allowed to eat any foods at break-time.[116] Rundle *et al.* found obesity to be associated with students who received free or reduced-price lunches.[117]

Four out of the five studies reported at least one school-to-student association that was statistically significant (p-value = <0.05).[115,116,117,118] All studies used a regression type of analysis, with two applying a multi-level model to separate compositional and contextual influences. Three studies used BMI as their primary outcome measure in line with International Obesity Task Force (IOTF) guidelines, [114,116,117,118] while Fox *et al.* applied guidelines recommended by the US CDC.[115,121] Harrison *et al.* used FMI in their model, which was derived from foot-to-foot bioelectrical impedance values.[116]

All authors acknowledged the limitations of a cross-sectional study design and that it was not possible to conclusively attribute associations between characteristics of the school environment and student BMI. Harrison *et al.* stated that foot-to-foot bioelectrical impedance measures of body fat did not measure the composition of the upper body.[116] Rundle *et al.* reported the exclusion of private schools as a limitation.[117] Four studies were limited by focusing on school-level factors that concerned just one side of the energy intake/expenditure pathway. We found much inconsistency in the number and type of variables adjusted for in final models. No studies reported adjustments for existing school-based programmes present at the time of data collection.

Despite authors reporting very few, if any, limitations to their instrument(s) used to collect school-level data, no study reported the validity or reliability of these measurement instruments. Each study collected their school-level data from a different source, either from school staff or their own data collectors. The authors offered little information on the theoretical framework underpinning their approach to the collection of school-level data.

3.6 Discussion

The five articles included in this systematic review showed poor-quality evidence in support of a relationship between the school environment and student weight status. Evidence was collected using a variety of instruments, with none having any validity or reliability testing, nor any reference to their development or theoretical framework. This finding cast significant doubt over the quality of research being done in this area.

In addition to the five articles meeting the selection criteria, a total of 65 peer-reviewed publications were identified that actually had the data needed to investigate the relationship between school- and student-level factors. However, the authors of these studies either elected not to report on the school-to-student relationship at baseline data collection, or they simply were not interested in the 'school effect' beyond the effect of the intervention being trialed. This finding indicates a possible bias against reporting non-significant results. Furthermore, it indicates a potential presumption amongst researchers that the school setting plays an important role in student weight status, despite a lack of quality evidence demonstrating such a relationship.

Our systematic review was not restricted by study design type; however, all five studies that met the selection criteria were observational. This may appear at first to make sense considering the exclusion criteria, but intervention studies have an opportunity to report the 'school effect' at baseline data collection, and therefore they would have met the selection criteria and been included in our narrative synthesis. Nonetheless, all five studies in this review were limited due to a cross-sectional study design. Cross-sectional studies may be prone to non-response bias if the participants who consented to take part in the study differed from those who did not, resulting in a sample unrepresentative of the general population.[122] Furthermore, only an association, and not causation, can be inferred from a cross-sectional study.[122] The NOS tool found just one of the five included studies to be of strong research quality. Most studies scored well on their outcome measure because most used BMI as their primary outcome, but the studies tended to fall short in other areas. So even if the five studies had used valid and reliable measurement instruments of the school environment – which are scarcely available, if at all – their findings would have still been limited due to the other factors noted in Table 3.11.

We decided to group school-level measures in line with the ANGELO framework to help sort the school-level results and to improve the transparency around the different environmental elements. We found that studies investigated a wide range of school-level factors, but there was a lack of consistency between studies. In their analysis, the authors tended to isolate certain parts of the school environment, or they captured multiple school-level components simultaneously. It is important to understand if different environmental elements are having greater influence than others on student weight status, or if they are only having an effect when grouped together. Future research must consider these possibilities in the study design phase and their analytical approach.

It is important that researchers in future aim to separate the contextual and compositional factors that could be influencing rates of student obesity. Multi-level modelling is one potential solution that can help to separate and unpick the specific factors influencing student obesity. A longitudinal study design can also help to improve the quality of research being done in this area. In addition, future observational research would be enhanced with follow-up data. In longitudinal studies, each participant is observed at multiple time points, thereby allowing changes in student- and school-level factors to be monitored over time.[122] However, because these factors were only observed once in the five studies included in my review, it was not possible to describe trends in rates of obesity between the students or schools.

Using the ANGELO framework, we found that the school-level variables related to school policies were the most common element investigated by researchers. For example, Veugelers & Fitzgerald (2005) investigated if a school had a policy in place to provide a healthy option in the school canteen.[114] However, there was only one example where a study looked at policy implementation, and it is arguably more important to know if a policy was actually being implemented, or if it was indeed being neglected. In terms of the economic environment, a surprising result was the lack of exploration by researchers in this area . It is well-established that pricing is a predictor of dietary choices and this is an area of the school environment that offers much promise. To illustrate, Briggs *et al.* (2013) found that a 10% tax on sugary-sweetened beverages has population-wide effects on their consumption, particularly in younger age groups; similar interventions may be effective in schools.[123]

Considering the objective nature of school-level factors related to the physical environment, it was unexpected that more research had not been done. An objective measure in this context is an estimate of a school-level factor such as the oval size, or food pricing, or the availability of sporting equipment. Because of their objective nature, these data types are important to comparative research. A much more difficult part of the school environment to investigate, however, is the socio-cultural environment. In the study by Rundle *et al.* (2012), the authors looked at the ethnic makeup of a school in association with student obesity.[117] However, a systematic review by Braun *et al.* (2013) highlights the difficulty and complexity of even defining ethnicity.[124]

Future research faces a significant challenge of measuring the school's impact, if present, on student weight status. We therefore recommended that researchers in future include objective measurements wherever feasible at both the school- and student-level. Such research should also aim to include school- and student-level factors relevant to both the food and PA environment, as these different types and levels of data will assist statistical techniques aiming to separate compositional and contextual factors. Finally, research should focus on identifying the modifiable risk factors and specific school-level features that are amenable to programmatic and/or policy intervention.

3.7 Summary of chapter

The aim of this review was to critically assess the methods used by researchers to demonstrate a school's effect on student weight outcomes. A total of 21,778 peer-reviewed articles was reduced down to just five articles which met the inclusion criteria. A further 65 articles potentially had the data required to meet the inclusion criteria, but for various reasons the authors did not report on the school-to-student relationship. Using the NOS QA tool, none of the included studies were found to be strong in terms of study quality. Overall, this review highlighted the scarcity of quality evidence demonstrating how the school environment is a determinant of childhood obesity. It showed that researchers have used research instruments of unknown quality to measure this relationship, with essentially no mention of any validity or reliability testing of the instruments used in their research. This latter finding raised important concerns around the standard of research being done in schools in relation to its hypothesised effect on student obesity. It revealed a potential bias against reporting non-significant results, as well as a possible presumption by the research community that schools are playing a significant role in childhood obesity prevention. In the next chapter, I present an outline of my research project, as well as a critique of the measurement instruments we used in the 'Healthy Together Victoria' (HTV) evaluation — a large-scale WHOCC-OP research project I co-led in Victoria, Australia.

- 4 -

BACKGROUND: Overview of research project and measurement instruments

4.1 Outline of chapter

In this chapter, I outline my contribution to a childhood obesity research project led by the WHOCC-OP, based at Deakin University in Geelong, Victoria. I introduce my research aims and objectives, as well as outline the ethical considerations of my research project. I conclude the chapter by describing in detail the measurement instruments we used to collect various student- and school-level data, evaluating their validity and reliability. Chapter Five then describes the method I followed prior to, during, and following the survey period.

4.2 The WHO Collaborating Centre for Obesity Prevention

In 2013, I was awarded a European Union PANAMA Exchange Grant to spend two months working for the WHOCC-OP at Deakin University. The WHOCC-OP was established at Deakin University in 2003 and it provides an inter-institutional collaborative network for the WHO around obesity-related research. The Centre's main purpose is to support obesity prevention programmes and initiatives at the country, inter-country, regional, inter-regional, and global levels. In 2013, the WHOCC-OP led plans to evaluate the Victorian Government's HTV intervention around its impact on childhood obesity. It was during my two-month visit to the WHOCC-OP that I became involved in this project; the HTV Evaluation Steering Committee needed a researcher to look at the impact of the school environment on student obesity. I later returned to the University of Oxford and submitted a research proposal, soon after I received ethics approvals from multiple bodies (see Section 4.5). I then returned to Geelong, Victoria, and spent the rest of 2013 co-leading the HTV evaluation survey.

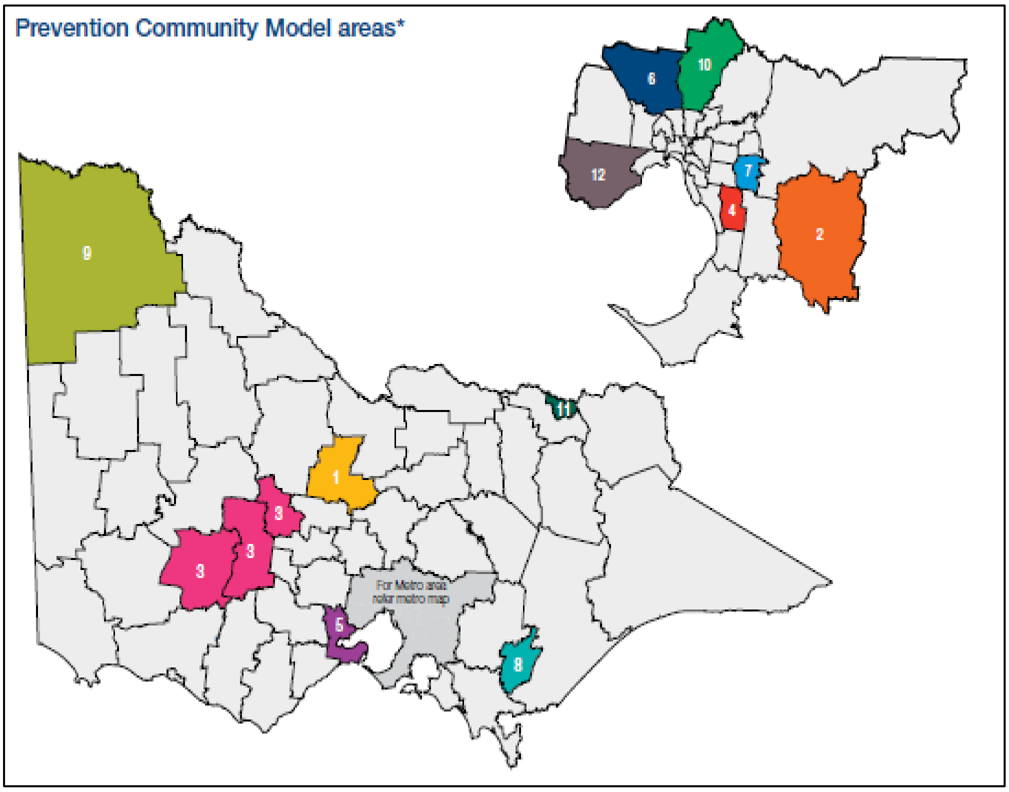
The following section provides a brief background to the WHOCC-OP and introduces the broader aims of the HTV evaluation. It was important that I fully understood these so that I could determine if they had any impact on my own research.

4.2.1 The 'Healthy Together Victoria' evaluation

In 2008, the Commonwealth Government of Australia allocated funding for five years (2009-10 to 2015-16) through the National Partnership Agreement on Preventative Health (NPAPH) to help slow the growth of lifestyle-related chronic disease in Australia, and to support Local Government Areas (LGAs) and community organisations to instigate community-based dietary and PA education programmes and healthy lifestyle initiatives.[125] In conjunction with the Council of Australian Governments, the Victorian Department of Health in 2012 announced the HTV intervention, which aimed to reduce the growth of avoidable lifestyle-related chronic illness in Victorian communities. A core component of this new strategy was the newly adopted 'Victorian Prevention System', which aimed to deliver tailored interventions to reduce chronic diseases at the community-level.[125]

The HTV intervention was co-developed by the Victorian Government Department of Health and the WHOCC-OP. It was rolled-out using a cluster-randomised control trial

(RCT) study design. Twelve HTV intervention sites across Victoria, covering 14 LGAs and approximately 1.3 million people, were randomly selected to trial the HTV intervention (see Figure 4.1).



1. Bendigo
2. Cardinia
3. Central Goldfields, Pyrenees, Ararat
4. Dandenong
5. Greater Geelong
6. Hume
7. Knox
8. Latrobe
9. Mildura
10. Whittlesea
11. Wodonga
12. Wyndham

Figure 4.1. Overview of the 12 HTV prevention areas (14 LGAs) within the state of Victoria, Australia (control areas not shown due to confidentiality)

The WHOCC-OP originally considered two evaluation designs; repeat measures and repeat cross-sectional. Following feedback from the Director of Biostatistics at the Faculty of Health, Deakin University, and work done by the HTV Evaluation Steering Committee for the HTV intervention, the repeat measures study design was rejected. It was believed that the expected drop-out rate would eventually create a bias and significantly less power in results. Therefore, the HTV Evaluation Steering Committee chose a repeat cross-sectional evaluation design. My research project would take place at baseline data collection, which meant that my results would be unaffected by the roll-out of HTV intervention.

The hypothesis by the HTV Evaluation Steering Committee was that they would observe a significant difference in mean zBMI scores between children in the intervention and comparison communities over a period of five years. The aims of the HTV intervention were:

1. To evaluate the effectiveness of a complex systems intervention in preventing childhood obesity within twelve randomly selected 'prevention' areas with 12 comparison LGAs; and,
2. To evaluate the effectiveness of 'systems change' in addressing two key risk factors for heart disease: unhealthy nutrition and physical inactivity.

The twelve matched control LGAs were randomly selected for comparison, but it was agreed that these LGAs remained confidential until the WHOCC-OP concluded their study. The 14 intervention LGAs – in partnership with local health organisations, local stakeholders, and general communities – would set out to lead comprehensive local efforts to support the development of a local prevention system.

The HTV intervention was designed to improve people's health by focusing on addressing the underlying causes of poor health in different settings, workplaces, and communities in order to help strengthen Victoria's prevention system.[125] A major focus of the strategy was to encourage healthy eating and PA, as well as to reduce the rates of smoking and harmful alcohol use. In order to achieve this, the HTV intervention encouraged communities to incorporate policies and strategies that supported "good health", with a major focus on the four aforementioned health risk factors.[125] To support this change across the 14 intervention LGAs, in 2014 a significant new workforce and extensive capacity-building was employed by the Victorian Government Department of Health to help ensure the skills and resources within these areas were strengthened and aligned over a period of five years.

Responsibility for the HTV evaluation was shared between the WHOCC-OP and the Victorian Centre for Excellence in Intervention and Prevention Science (CEIPS). Each community included in the HTV intervention targeted various chronic diseases with localised strategies. Evaluations for other chronic diseases were set to take place during the roll-out of the HTV intervention, but childhood obesity was identified as a priority across all of the HTV intervention sites and additional funding was then granted to specifically evaluate the HTV's effectiveness in reducing childhood obesity. As noted, the HTV intervention – concerning childhood obesity – was evaluated using a repeat cross-sectional study design.

An important consideration in the HTV evaluation study design was how many participants would be needed to observe the effect of the HTV intervention, if present, by comparing changes in zBMI in the intervention group with changes in the control group. The HTV evaluation was designed to collect objective measurements of child height and weight across Years 4, 6 (primary schools), 8, and 10 (secondary schools) annually for a period of five consecutive years, beginning in Term IV in late-2013. For the purposes of the HTV evaluation, the intervention areas were viewed as the primary exposure and zBMI scores as the primary outcome measure.

The HTV Evaluation Steering Committee's sample size calculations were generated using the GenStat 14.2 statistical package and were based on a comparison of zBMI in children in the intervention versus comparison communities; the significance level in the power calculations was set at 0.05 and the power at 0.80. The HTV Evaluation Steering Committee applied the baseline zBMI scores found in Victorian primary school children who participated in the Be Active Eat Well (BAEW) study — a similar, but smaller-scale, investigation into childhood obesity in 2003 that was also led by the WHOCC-OP.[126]

Baseline zBMI was 0.65 with a standard deviation (SD) of 0.93; these two figures were important for the sample size calculations, because the relationship between the estimates and the variance significantly impact the number of study participants estimated to see the desired change of the primary outcome (student zBMI). The HTV Evaluation Steering Committee set the difference in zBMI score at 0.09, which was observed in BAEW study.[126] The final sample size calculations determined by HTV Evaluation Steering Committee included a sample of four classes of 25 students (Years 4, 6, 8, 10) across the 26 LGAs over a period of three consecutive years; 7,200 students / 3 years = 2,400 students per year.

4.3 Overview of my research project

To a large extent, my research project was shaped by the aims of the HTV evaluation. Prior to my joining of the project leadership team, the WHOCC-OP had randomly selected the 26 LGAs included in the study, as well as chosen the measurement instruments to be used at baseline data collection. I describe these instruments in detail in the following sections. My main contribution to the HTV evaluation was to co-lead the collection of the student- and school-level data at baseline, and to later identify associations between school-level measures of the environment and weight-related data amongst the primary school students. As noted in Chapter One, my research project included one primary research question, which was then anchored by three subsidiary research questions. My primary research question was:

RQ1. Is there an association between student zBMI and the number of school environmental actions in place to promote healthy eating and PA amongst students, as measured by the BAEW questionnaire?

while my subsidiary research questions were:

RQ2. How do researchers characterise the school environment in determining its effect on student obesity? (systematic review)

RQ3. Is there an association between student zBMI and either of the school Food or PA environments?

RQ4. Is there an association between student MVPA, as measured by accelerometery, and the number of school environmental actions in place to promote PA amongst students, as measured by the BAEW questionnaire?

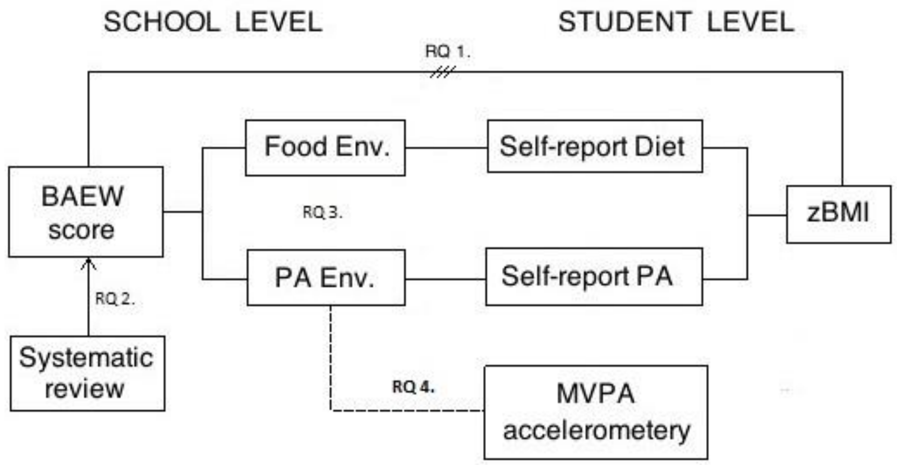


Figure 4.2. Flow diagram of research questions

RQ = Research Question; BAEW = Be Active Eat Well; Env. = Environment; PA = Physical Activity; MVPA = Moderate to Vigorous Physical Activity; zBMI = Body Mass Index z-scores

In the following section, I describe the student- and school-level data we collected that were relevant to my research project. In line with my primary and subsidiary research questions, my research project worked to achieve the following four central objectives:

1. To complete a systematic review of the evidence with respect to how researchers have characterised the school environment in determining its effect on student obesity;
2. To collect valid and reliable data on student zBMI and weight-related factors;
3. To collect valid and reliable school-level data on the promotion of healthy eating and PA in schools; and,
4. To investigate associations between student- and school-level factors.

4.4 Measurement instruments

In this section, I describe the measurement instruments we used in the HTV evaluation to collect student- and school-level data. I describe in the next chapter how I constructed my dependent and independent variables using these data — which I later included in my descriptive and regression analyses (see Chapters Six and Seven). At times when I refer to the validity or reliability of a specific instrument, I am referring to the definitions put forward by Kelly *et al.* (2016); although not all types of validity and reliability are cited (see Table 4.1).[127]

Table 4.1. Validity and reliability definitions [127]

Validity: The extent to which a measurement is representative of the true scientific value; taking "true" to mean an exact representation of what happened, free from all possible sources of error or bias.	
Construct validity	A combined assessment of face, content, and [concurrent, convergent or criterion] validity for a measure within the desired study population.
Face validity	The extent to which a measure looks like it will, or appears to, provide the desired information. Assessed by expert consensus.
Content validity	The extent to which a measure covers all aspects of the intended behavioural or physiological domains or dimensions. Assessed by examination of domain or dimension of interest.
Convergent validity	The extent of the agreement with another (non-criterion) measure that should assess the same parameter based on face and content validity. Assessed quantitatively. Useful when the criterion is very resource intensive.
Criterion validity	The extent of the agreement between a measure and another already held as being a criterion or gold standard. Assessed quantitatively. Called absolute validity when compared to measure known to provide perfectly true values.
Concurrent validity	Assessment of convergent or criterion validity when measures taken at same time.
Predictive validity	Assessment of convergent or criterion validity when measures taken at different times.
Internal validity	The extent to which conclusions drawn from the experimental data are free from confounding issues which cause bias such as reactivity and missing data. Assessed by examination of relevant issues.
External validity	The extent to which conclusions drawn from the data are generalisable to the wider populations. Assessed by examination of age, sex, ethnic origin, socio-economic status, etc., of study sample. This could be assessed by a theoretical justification or empirical demonstration such as field testing and small scale "proof of concept" studies. These should assess participant feedback (e.g. satisfaction and burden) as well as data issues.

Reliability: The extent to which a tool gives measurements that are consistent, stable, and repeatable.	
Test-retest reliability	The extent to which test scores are consistent from one test administration to the next; keeping as many conditions (e.g. researcher, timing, preparation, etc.) as possible unchanged. Assessed quantitatively.
Inter/intra-rater reliability	The extent to which test scores are consistent when measurements are taken by different people using the same methods (inter-rater) or at different times by the same person (intra-rater). Assessed quantitatively.
Inter/intra-instrument reliability	The extent to which test scores are consistent when measurements of the same thing are taken by different versions of the same instrument (inter-instrument) or repeatedly by the same version of an instrument (intra-instrument). Assessed quantitatively.
Behavioural reliability	The extent to which stability in behaviour has been considered when assessing other aspects of reliability.

Kelly *et al.* did not aim to re-define the meaning of validity or reliability types with their publication. Instead, the authors aimed to provide clarity on these definitions in order to improve the quality of research being done, particularly in the areas of PA and sedentary behaviour research. Furthermore, Kelly *et al.* stressed that further work was needed in this area and that any criticisms of their framework were welcome, yet at the same time only served to strengthen their position that there is a general lack of consistency in validity and reliability definitions.[127]

Table 4.2 below describes the measurement instruments used in the HTV evaluation, as well as the types of validity and reliability testing each instrument had undergone as reported in the peer-reviewed literature, which is described more in the following sub-sections.

Table 4.2. HTV evaluation outcomes of interest and measurement instruments

Item	Outcome of interest	Instrument/ Measure	Quality
Anthropometry	- Student zBMI - O&O prevalence	Height (cm); Weight (kg)	WHO BMI growth reference standards
Diet	- Proportion of students meeting national dietary guidelines (2014) for fruit and vegetable intake	Children's Dietary Questionnaire (CDQ)[128]	Fruit & vegetable intake 7-day test-retest validity correlations (r = 0.58)
Physical activity	- Proportion of students meeting national PA guidelines (2014) - Daily MVPA accelerometery	School Health Action, Planning and Evaluation System (SHAPES);[129] GT3X+ accelerometers	PA recall with avg. MVPA min.d-1 7-day test-retest validity correlations (r = 0.44)
Mental Health (Year 8-10 only)	- Depressive symptom score	Short Mood and Feelings Questionnaire (SMFQ)[130]	Internal reliability (alpha = 0.85)
Quality of Life (Year 8-10 only)	- Psychosocial health summary score - Physical health summary score	Pediatric Quality of Life Inventory (PedsQL)[131]	Internal reliability (alpha = 0.80)
School Environment Audit	- School Food and PA environment	- Be Active Eat Well (BAEW) questionnaire[132] (primary schools) - It's Your Move (IYM) questionnaire (secondary schools)[133]	High Logic and Face validity

4.4.1 Anthropometry

My primary outcome measure was student zBMI. I refer at times to O&O because it is potentially understood by a wider audience, but student zBMI was strictly applied in my analysis. I define both indicators of weight status in this section.

The Australian Government NHMRC in 2013 released the 'Clinical Practice Guidelines for the Management of Overweight and Obesity in Adults, Adolescents and Children', which recommended the use of BMI to define O&O in Australian children aged two to 18 years.[134] BMI is calculated by dividing weight in kilograms (kg) by height in metres (m), squared (^{2}); or kg/m^2.[135] As described in my methods (Chapter Five), height and weight were collected for all students participating in the HTV evaluation survey.

Criteria used to define child O&O can depend on the international growth reference. For the purposes of my thesis, I used the WHO's BMI growth reference standards, which applied age-sex-specific BMI z-scores to define overweight (+1.0 to 2.0 SD) and obesity (+2.0 SD).[136] An alternative reference that I could have used was the IOTF's growth reference, which also provides age-sex-specific cut-points to define O&O amongst youth.[114] However, I chose the WHO growth reference standards to allow for greater representativeness of my results and because that my research project was done in collaboration with the WHOCC-OP.

BMI percentiles and z-scores are commonly used to assess anthropometric measures. The advantage of z-scores compared to percentiles is that they are calculated based on the distribution of the reference population (their mean and SD), thus reflecting the reference distribution.[137] Other advantages of z-scores includes that they are comparable across age, gender, and anthropometric measures (as standardised quantities), and because they can be analysed as a continuous variable.[137] A disadvantage of z-scores is that they are not as straightforward as percentiles to explain to the general public.

4.4.2 Dietary behaviour

As discussed in Chapter Two, the examination of diet quality in childhood has been subject to increased attention over recent decades, given the increased availability of energy-dense and nutrient-poor foods, and direct marketing of these foods to children.[10] However, there is little consensus regarding the best method for assessing the dietary intake of children. According to a review by Collins *et al.* (2010), dietary intake cannot be measured without error in any age group, but measuring dietary intake in childhood compared with adults presents unique challenges relating to age and cognition, with portion-size estimation particularly difficult.[138] In trying to overcome these challenges, Collins *et al.* looked at the evidence-base around how researchers had been measuring dietary intake in children and adolescents in the context of O&O.[138]

The review highlighted many gaps in knowledge and limitations in the literature, and drew attention to the challenge for researchers in estimating changes in food intake in a valid and reliable way.[138] The authors attempted to address some of the gaps in the literature by describing the most commonly used dietary methodologies — reviewing their advantages, disadvantages, and applications for children. They found that younger children were generally more willing to provide information regarding their dietary intake, with children aged six to eleven years particularly enthusiastic, whereas adolescents aged twelve years and above were less so (students in my research were aged 9-13 years).[138] Collins *et al.*

(2010) also reported the various types of dietary assessment tools used by researchers, ranging from prospective, written food records to retrospective, interview-led, food recall questionnaires. They found that the most commonly used dietary assessment tool was the food frequency questionnaire (FFQ), which was the type of dietary assessment tool selected by the HTV Evaluation Steering Committee for the HTV evaluation.

FFQs are most often used in population studies because they are quick and inexpensive.[139] FFQs ask respondents to report their usual frequency of consumption of each food item from a list of foods for a specific time. FFQs can be self-administered (usually in larger studies) or interview-administered. According to Collins *et al.* (2010), FFQs are designed to only capture usual food intake and they generally report higher estimates of dietary intake when compared to food records and recalls, a limitation that the HTV Evaluation Steering Committee had considered.[138] Overall, the committee ordered a range of FFQs by their validity correlations, selecting the tool to be used in the HTV evaluation based on its prior application among Australian school children, ease of administration, questionnaire length, validity and reliability properties, and administration type.

Although the HTV Evaluation Steering Committee acknowledged that the 24-hour food recall diaries were a more valid and reliable measure of dietary intake, the committee decided that 24-hour food recall diaries were too burdensome on study participants, as well as inappropriate for children aged 10-12 years. The 24-hour food recall diaries are also typically used to collect information on energy intake and macro- and micro-nutrient intakes, which was again thought to go beyond the central aims of the HTV evaluation — the committee was more interested in knowing if students were meeting the Australian dietary guidelines (2014) for daily fruit and vegetable intake. Ultimately, the committee chose FFQs as the most appropriate dietary assessment tool for meeting the aims of the

HTV evaluation and then short-listed two leading measurement instruments: the Child Nutrition Questionnaire (CNQ) and the Children's Dietary Questionnaire (CDQ).[128,140]

The committee preferred the CDQ ahead of the CNQ tool because it had been previously validated amongst Australian school children aged four to 16 years, and it also had a demonstrated higher 7-day test-retest validity for fruit and vegetable intake (r = 0.58).[128] Development of the CDQ was based on the Australian dietary guidelines (2003). To ensure that inclusion of all types of relevant foods were in the CDQ, and to reportedly optimise content validity, a panel of four paediatric dietary experts reviewed all items. The readability of the questionnaire was assessed by pilot testing a draft form with four parents. The outcome was a 28-item semi-quantitative FFQ designed to examine the intake of those foods for which intake is recommended (positive indicators: fruit, vegetables, water, reduced fat products) and for those foods that are discouraged (negative indicators: high-fat/sugar foods [non-core foods], sweetened beverages, full-fat dairy products).[128] Rather than measuring actual amounts or specific types of foods consumed, the CDQ aimed to assess patterns of food intake amongst children.

According to Magarey *et al.* (2009), the CDQ's internal consistency, test-retest reliability, and relative validity were tested among samples of parent-respondents for school-aged children — meaning that this instrument was designed for parents to complete the FFQ about their own children.[128] I describe in Chapter Five how the CDQ was administered, but an important consideration to note in regards to any future interpretation of the dietary data we collected is that the CDQ was administered during the HTV evaluation by either myself or another member of the study leadership team to a class of Year 4 or Year 6 students — not how the instrument was originally intended to be used, although the CDQ was designed to be used at the group level.

4.4.3 Physical activity behaviour

PA behaviour is commonly examined through self-report PA Questionnaires (PAQs) in population-level studies, as they are relatively simple and inexpensive and have been associated with health outcomes in children and adolescents.[141,142] Accurate measurement of human movement, however, remains a substantial challenge; in particular, when it is measured using PAQs.

In 2012, Helmerhorst *et al.* published a review on the reliability and validity characteristics of PAQs, with the aim to quantitatively compare the performance of PAQs included in their previous systematic review (1999) with the more recently developed PAQs (up to December 2011).[143] Their review included 31 studies testing 34 newly developed PAQs compared with 65 previous studies examining 96 PAQs. Despite the authors waiting twelve years between their first review and an update, they found that the newly developed PAQs were not performing substantially better than the PAQs included in the previous review.[143] This is an obvious concern for the direction of research in this area. The authors reported that very few PAQs were strong in terms of both validity and reliability.[143] While the majority of PAQs scored reasonably well in terms to reliability, their validity was generally reported as moderate, at best. This is consistent with the assessment by the HTV Evaluation Steering Committee when assessing the most appropriate PAQ that was to be used in the HTV evaluation. A total of five different PAQs were short-listed by the committee:

- The School Health Action, Planning and Evaluation System (SHAPES) questionnaire;[129]
- The Children's Leisure Activities Study Survey (CLASS);[144]

- The Adolescent Physical Activity Recall (APAR) questionnaire;[145]
- The Multimedia Activity Recall for Children and Adolescents (MARCA);[146] and,
- The Child and Adolescent Physical Activity and Nutrition Survey: Physical Activity (CAPANS-PA) questionnaire.[147]

Like the FFQs, the committee ordered the PAQs on their prior application among Australian school children, ease of administration, questionnaire length, validity and reliability properties, and administration type. Despite validity testing being done in adolescents, the HTV Evaluation Steering Committee selected the SHAPES questionnaire as the most appropriate measurement instrument to meet the aims of the HTV evaluation.[129] The committee considered it particularly advantageous that it was computer-readable for data entry. The SHAPES questionnaire was designed to provide schools with feedback that enabled them to better understand patterns of PA within their school, as well as to recognise what is, and what is not, in place to support PA behaviours, and how to plan and evaluate prevention efforts.[129]

The SHAPES questionnaire had been reported in the peer-reviewed literature as having acceptable reliability and validity.[148] According to Wong *et al.* (2006), the SHAPES questionnaire had moderate validity correlations for self-reported and accelerometery average MVPA minutes per day (r = 0.44, p-value = 0.01), which was tested amongst a sample of Canadian youth aged eleven to 18 years; however, students tended to over-report PA behaviours.[148] The instrument's test-retest reliability was assessed by administering it twice and one week apart on a sample of 2,812 students in Years 9 – 12 (ages 15 – 18). The kappa coefficient for the 7-day test-retest reliability of the SHAPES questionnaire indicated moderate agreement (mean 0.57 ± 0.24).

The SHAPES questionnaire asked participants to recall their PA behaviour over the previous seven days. During the HTV evaluation, the SHAPES questionnaire was used to collect PA behavioural data for classes of children and adolescents in Years 4, 6, 8, and 10. A drawback of the questionnaire was its length, which included 45 unique items. I provide a more detailed description of how we administered the SHAPES questionnaire and how I utilised the collected data in Chapter Five.

4.4.4 Accelerometery

The Australian national PA guidelines (2014) recommended that children aged 5-12 years do at least 60 minutes of MVPA each day.[81] A study by the ABS using self-report PA behaviour data showed that 19.6% of children and adolescents (aged 5-17 years) engaged in sufficient levels of daily MVPA to confer the health benefits.[149] As noted in Chapter Two, objective measures of PA behaviour such as with accelerometery are the preferred method as they provide more valid and reliable measures than any self-report PA data. Accelerometers provide a continuous measure of the frequency and amplitude of human movement to generate a "count", with larger counts considered indicative of higher intensities of PA.[150] Prince *et al.* (2008) and Lubans *et al.* (2011) have each published systematic reviews that looked at the advantages and disadvantages of direct versus self-report measures of PA behaviour.[151,152]

The review by Prince *et al.* aimed to compare and to determine the extent of agreement between accelerometery and self-report measures of PA behaviour in adults.[151] It extracted data from 187 studies and included observational and experimental research. They found that the type of measurement method had a significant impact on the observed level of

PA behaviour, and although no clear patterns emerged in mean correlates between direct and self-report measures, the self-report measures were both higher and lower than the directly measured levels of PA behaviour, which poses a problem for a study that relied on self-report measurements.[151]

Looking at younger age groups, Lubans *et al.* (2011) published a review that critiqued the validity and reliability of instruments used to assess the multiple components of sedentary behaviour in children and adolescents.[152] Twenty-six studies met the inclusion criteria, but only five studies demonstrated the utility of accelerometers; the latter finding is likely to be because accelerometers are relatively much more expensive and burdensome on participants compared to self-report questionnaires. Similar to what was reported by Wong *et al.* (2006), Lubans *et al.* found that children over-reported their PA behaviours compared to accelerometery. However, while accelerometers can classify sedentary behaviour more accurately than self-report questionnaires, they still did not provide information about the precise type of sedentary behaviour or give any context.[152]

A concern about the validity and reliability of self-report data was a feature of both reviews. Prince *et al.* and Lubans *et al.* together called for more objective measures to be used in future PA research.[151,152] This finding is essentially what drove the HTV Evaluation Steering Committee to complement the SHAPES questionnaire data with a sample of accelerometery data. However, the committee had difficulty in sourcing enough accelerometers so that one could be handed-out to every student who participated in the HTV evaluation. In the end, enough accelerometers were sourced so that we could give approximately one to every second student — I explain this in more detail in Chapter Five.

For the HTV evaluation, we used ActiGraph GT3X and GT3X+ accelerometers (ActiGraph, Pensacola, Florida, US) to collect objective measures of PA behaviour. We were able to overcome the intergenerational issue of the differing ActiGraph accelerometer models by selecting a 15-second epoch and 30-hertz sampling rate, which had previously been shown to have strong agreement with total vertical axis counts, total vector magnitude (VM) counts, and MVPA levels amongst children and adolescents.[153]

Different accelerometery studies have used different count cut-points and this can have important implications for research. For example, Mota *et al.* (2007) compared the count cut-points from two different models – Freedson *et al.* (1998) and Puyau *et al.* (2002) – on a sample of 62 children and adolescents aged eight to 16 years.[154,155,156] Study participants wore an accelerometer for three consecutive days. Mota *et al.* reported that the rates of observed PA among participants significantly differed depending on which cut-points were used.[154] For the purposes of the HTV evaluation, the HTV Evaluation Steering Committee applied count cut-points developed by Romanzini *et al.* (2014).[157]

The count cut-points by Romanzini *et al.* were developed specifically for the ActiGraph GT3X accelerometer model.[157] Using a sample of 79 children and adolescents aged ten to 15 years, Romanzini *et al.* had collected accelerometery and oxygen consumption (VO_2) data at rest and at eleven different intensities of PA. The count cut-points were then determined by matching the eleven different observed activities with Receiver Operating Characteristic (ROC) curves — a criterion for sedentary and MVPA count cut-points which determine the point at which sensitivity and specificity are maximised.[157] The sensitivity is maximised by correctly identifying activities at or above the observed cut-point for intensity, while the specificity is maximised by correctly excluding activities below the observed cut-point for intensity. Metabolic equivalent units (METs) were next individually computed by dividing the $\dot{V}O_2$ values recorded during each activity (ml $\times$ kg $\times$ min^{-1}) by the $\dot{V}O_2$ values recorded at rest (ml $\times$ kg $\times$ min^{-1}). Finally, total VM counts per minute (counts.min^{-1}) were calculated to give an indication of the volume of PA and the total VM counts.min^{-1} utilised information from three axes via the equation:

$$VM = \sqrt{(Axis\ 1)^2 + (Axis\ 2)^2 + (Axis\ 3)^2}$$

and this was calculated per epoch of time.[158] METs were then assigned to VM counts.min^{-1} and this was used to classify the intensity of activity as: Sedentary (≤1.5 METs), Light (1.5 to 2.9 METs), and MVPA (≥3.0 METs). Nonwear-time was identified by periods in which ≥60 minutes of consecutive zero counts were obtained, with a 1-2 minutes allowance of counts between 0 and 100. Wear-time was calculated by subtracting nonwear-time from 24 hours, and a valid day was considered if ≥600 minutes per day (mins.d^{-1}) of wear-time was recorded.[159] Only participants with data that had ≥3 days of monitoring were included.

4.4.5 School environment

Schools have become the main setting for single- and multiple-intervention approaches to improve eating and activity behaviours in childhood. As noted in Chapter Two, a wide range of individual-level, environmental, and psycho-social influences are associated with PA and dietary behaviours, and the focus on the school environment is understandable given the sheer volume of time children spend in schools. Moreover, the robust structures that influence these environments are relatively easy to manipulate. It was during the 1990s that Professor Swinburn (Co-Director of the WHOCC-OP) led a push to better understand the impact of the school environment on student eating and PA behaviours — in particular, how an environmental intervention can help to prevent obesity. This research was in large part motivated by a lack of evidence showing the level of impact that schools were having on promoting healthy eating and PA behaviours.[160,161]

An outcome of Swinburn's work was the ANGELO framework — a conceptual model for understanding the obesogenicity of different environments.[113] As noted in Chapter Three, the ANGELO framework was developed in order to provide researchers with a practical tool for prioritising environmental elements, with a strong focus on the proposed "four pillars" of different micro- and macro-environments: the economics, physical, political, and socio-cultural elements.[113] This research later provided the foundation for two measurement instruments that aimed to assess the obesogenicity of schools: the BAEW questionnaire for primary schools (see Appendix Three) and the 'It's Your Move' (IYM) questionnaire for secondary schools.[132,133]

The BAEW and IYM questionnaires have previously been applied to large, community-based intervention studies in schools across Victoria, Australia. They are both completed at the school-level and there is no burden on the student population. Neither instrument has undertaken comprehensive validity or reliability testing. However, the BAEW and IYM questionnaires have been reported in the peer-reviewed literature as having high logic and face validity, with the BAEW questionnaire having contributed to multiple peer-reviewed publications.[132,133] No other reference to the validity or reliability of the BAEW questionnaire could be found in the peer-reviewed literature, so it was assumed that no other quality assessment was done on this measurement instrument.

The BAEW questionnaire is comprised of 126 questions, but it was not possible for a school to answer all 126 questions. The BAEW questionnaire had not previously been stripped back to its core list of questions related to the promotion of healthy eating and PA in primary schools. The BAEW questionnaire includes many "If Yes" and "If No" pathways, so a large portion of the questions do not get used per school because of the way the questionnaire is constructed.[132] For example, Sections B and C of the BAEW questionnaire – with the exception of one question about canteen space availability (Q. 27) – ask entirely the same set of questions regarding the food and beverages sold at the school. The only difference between Section B and Section C is that Section B concerns the "Internal Canteen Service" (Questions 8–34) and Section C the "External Canteen Service" (Questions 35–60). In addition, Section A is confined to school demographics (Questions 1–7) and does not collect any information regarding the promotion of healthy eating and PA amongst students. A visual representation of the data reduction process that I applied to the BAEW questionnaire is presented in Figure 4.3, which I describe in more depth in Chapter Five.

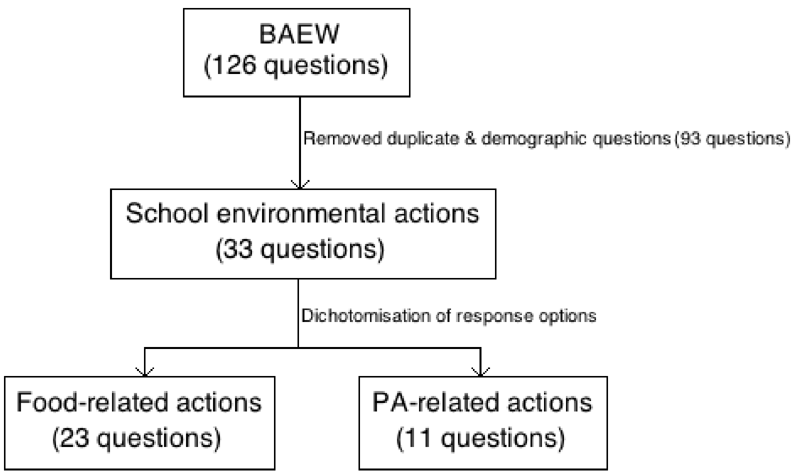


Figure 4.3. Reduction of BAEW questionnaire

Despite the BAEW questionnaire including 126 questions, only 33 questions were unique to a specific school environmental actions. Table 4.3 presents a list of the 33 questions related to the promotion of healthy eating and PA in primary schools. I describe in Chapter Five how these data were then transformed for statistical purposes and provide more information on the data reduction process in Appendix Five.

Table 4.3. BAEW questions related to the promotion of healthy eating and PA

No.	Be Active Eat Well questionnaire items
1	Does your school have a written policy promoting healthy eating?
2	How effective has this policy been on overall healthy eating?
3	Is making a profit an important part of the school foodservice?
4	Does your school have a written policy for types of foods sold by the foodservice?
5	What rating would you give the nutritional value of food sold?
6	What rating would you give for teachers acting as role models for healthy eating?
7	Does your school have a pricing policy to encourage the sale of healthy foods?
8	Does the canteen routinely promote healthy food choices?
9	Is the canteen food menu reviewed on a regular basis?
10	Is fruit available by the school foodservice?
11	Is low-fat milk available by the school foodservice?
12	Is low-fat yoghurt available by the school foodservice?
13	Are filled rolls/ sandwiches available by the school foodservice?
14	Are lollies/ sweets available by the school foodservice?
15	Are hot chips available by the school foodservice?
16	Are energy/ sugary drinks available by the school foodservice?
17	Are crisps available by the school foodservice?
18	Are hot pies available by the school foodservice?
19	Do you have a written policy promoting physical activity?
20	How many hours of formal physical education classes per week?
21	What rating would you give regarding how adequate your indoor play area is?
22	What rating would you give regarding how adequate your outdoor play area is?
23	What rating would you give teachers acting as role models for physical activity?
24	What rating would you give for the quality of available sporting equipment?
25	Does your school have any events sponsored by soft drinks, fast food or confectionary companies?
26	Are students allowed to eat in the classroom?
27	Does your school have a vegetable garden?
28	Does your school provide copies of healthy eating and physical activity policies to parents?
29	To what extent does your school have implemented a policy to reduce local traffic congestion?
30	To what extent does your school have implemented a student pedestrian safety program?
31	To what extent is does your school have implemented a cycling safety program?
32	To what extent does your school have implemented a cycle storage facility?
33	Does your school provide a breakfast service before school?

School Location and School Type

Section A of the BAEW questionnaire collected a limited amount of information relevant to the school's demographics. From these data, I was able to create a variable for the School Type and the School Location. I describe how these data were transformed for statistical purposes in Chapter Five, but in short three types of schools were included in the HTV evaluation: Government, Private, and Independent. While School Location was determined by postcode and I later used these data to categorise schools as either Urban or Rural.

Socio-economic status

Lastly, the Australian Bureau of Statistics (ABS) broadly defined socio-economic advantage and disadvantage as "people's access to material and social resources, and their ability to participate in society".[162] For the purposes of my analysis, I created another variable to measure each student's socio-economic status. I describe this variable in more detail in Chapter Five, which used individual-level postcodes to create an indicator socio-economic status.

4.5 Ethical approvals

My research project involved human participants, notably children, so it was important to seek ethics approval from the following institutions:

- University of Oxford Central University Research Ethics Committee (CUREC) (MSD-IDREC-C1-2013-168)
- Deakin University Human Research Ethics Committee (2013095-130822-M-o)
- Victorian Government Department of Health (ID. 2013_002013)
- Australian Catholic Education Office (HTCE_05-05-13)

I also completed ethical training courses from the National Institutes of Health (NIH) Office of Extramural Research and Deakin University.

4.6 Summary of chapter

In this chapter, I presented my research questions and described how they sat within the broader aims of the HTV evaluation. The measurement instruments we used in the HTV evaluation varied in regards to the quality of validity and reliability testing. However, many factors were taken into consideration by the HTV Evaluation Steering Committee in selecting the most appropriate tools and their validity and reliability were not the only consideration. For example, the CDQ was chosen in part because it is computable-readable — a major advantage in population-level surveys. The CDQ only had moderate validity and reliability for measuring the daily intake of fruit and vegetables, which was further limited due to the fact that we administered the questionnaire to classes of students rather than it being completed by parents, which is how it was designed to be used. The SHAPES questionnaire was designed to better understand patterns of PA within schools. It has been reported in the peer-reviewed literature as having acceptable reliability and validity, but this testing was undertaken amongst Canadian adolescents. The HTV Evaluation Steering Committee had concerns about relying on self-report PA behavioural data. Fortunately, we were successful in a grant application just prior to the beginning of the survey so that we could purchase GTX3 accelerometers, which provided an objective measure of student PA. At the school-level, the BAEW questionnaire was reported to have high logic and face validity in the peer-reviewed literature, but little else had been published with reference to its validity and reliability. I found that the BAEW questionnaire contained 33 unique questions, with most of the 126 questions included in the BAEW questionnaire repetitive or irrelevant to a school's promotion of healthy eating and PA. The next chapter describes the method we followed in the HTV evaluation, as well as my approach to data analysis.

- 5 -

METHOD: Data collection and data transformation

5.1 Outline of chapter

In this chapter, I present the data collection protocols we followed throughout the HTV evaluation. I describe the aims of my research project in the broader context of the HTV evaluation, as well as list the student- and school-level data we collected using the measurement instruments described in Chapter Four. I conclude the chapter with a description of how I transformed these data into dependent and independent variables in preparation for further analysis.

5.2 Research project

During the HTV evaluation, I was one of three full-time researchers responsible for day-to-day operations. Professor Allender, WHOCC-OP Co-Director, oversaw the wider project, while Dr. Strugnell was the Project Leader during the survey period. In partnership with Mr. Haywood, a PhD student at Deakin University, I worked under Dr. Strugnell's direction for the six months I spent in the field, leading up to and during Term IV of the 2013 primary school calendar.

Figure 5.1 presents the key milestones of my thesis and in the survey period in Victoria, Australia.

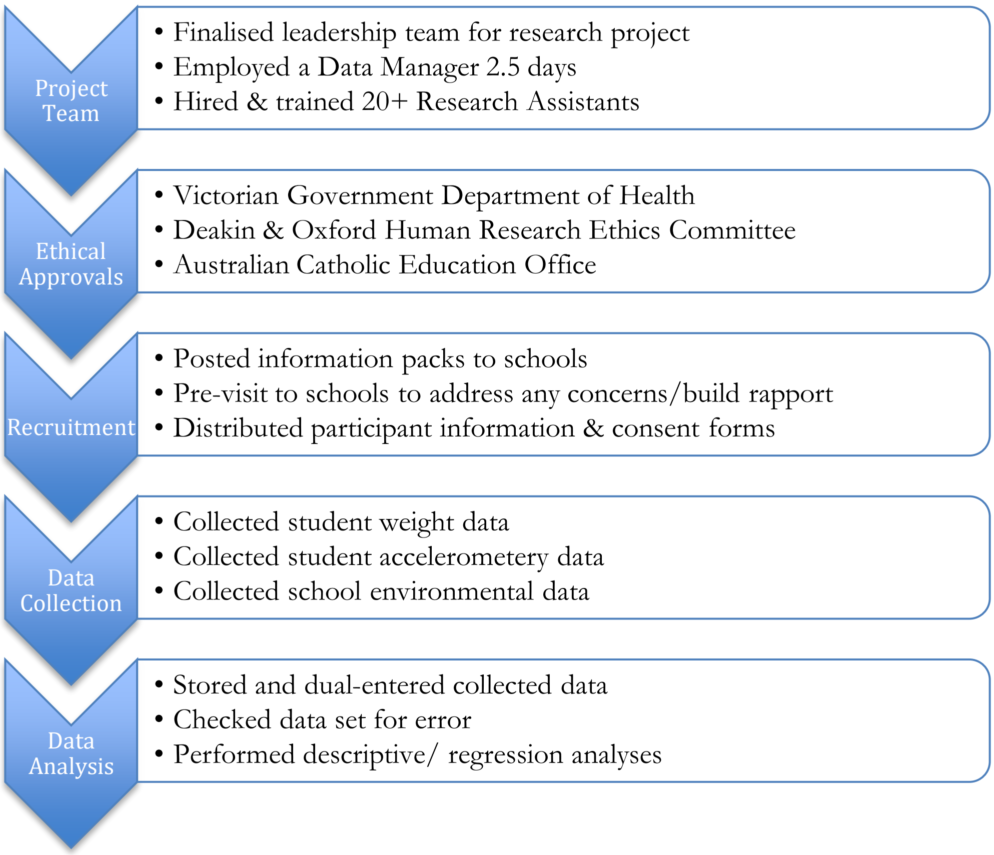


Figure 5.1. Key research milestones

As noted in Chapter Four, 26 different LGAs across Victoria were included in the HTV evaluation. Data collection was divided evenly between Dr. Strugnell, Mr. Haywood and I. However, the HTV Evaluation Steering Committee (myself included) were successful just prior to the survey period in a small grant application to the Australian Government NHMRC to employ a fourth member of the project leadership team. We then employed Ms. Malakellis as a Data Manager 2.5 days per week, who managed six LGAs. Mr. Haywood and I then teamed up and co-managed twelve LGAs, while Dr. Strugnell took responsibility for the remaining eight LGAs.

In the months leading up to the survey period, we recruited 20+ Research Assistants. Approximately 450 people applied for the role and I was responsible for screening one-third of applications — interviewing the top 20 applicants. The project leadership team organised two days of training for the Research Assistants we employed, and in preparation for this I co-wrote manuals for the Research Assistants to follow during the survey period. These manuals included:

- Participant Information and Consent Forms;
- Equipment checklists;
- Protocol for collecting anthropometry and questionnaire data; and,
- Fire and safety guidelines.

5.3 Recruitment

Once the HTV Evaluation Steering Committee received ethics approval, we randomly selected three primary schools and three secondary schools within 26 LGAs using the statistical package STATA IC 13.0. If all three schools in an LGA declined to participate in the study, a further three schools were randomly selected (with the three schools removed). This process was repeated until at least one primary and one secondary school had agreed to participate in the HTV evaluation or all schools had declined — the latter never eventuated. No data were collected on students or schools who declined to participate.

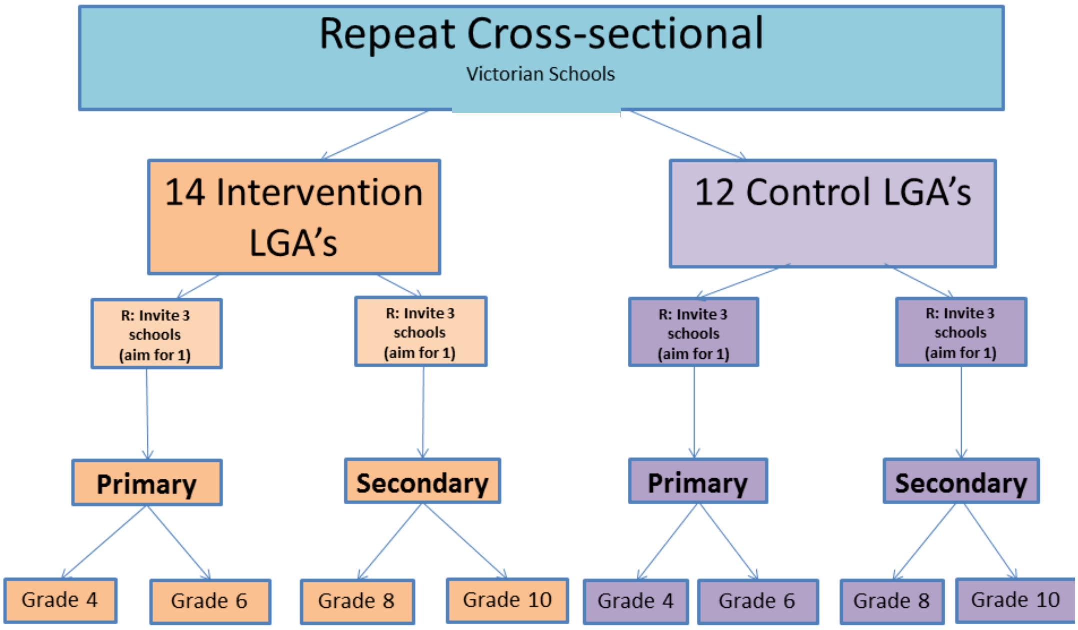


Figure 5.2. Recruitment of primary and secondary schools in the HTV evaluation

As noted in Chapter Four, the HTV evaluation was open to Government, Private, and Independent schools, and all students in Years 4, 6, 8, and 10 (see Figure 5.2). We sent packages to every school that was randomly selected, which included a comprehensive overview of the study, student consent forms, and examples of the questionnaires we'd be using. It was procedure to then follow-up with a phone call after five business days to ensure that the school had received the package. We offered to also visit the school in-person if the principal had any concerns or questions in order to help address them, as well as to build a positive working relationship with the staff and students.

5.4 Pre-data collection

In the school term prior to the data collection period, Mr. Haywood and I visited most schools that agreed to participate in the HTV evaluation. Whilst there, we distributed Plain Language Statements and Consent Forms to all students in Years 4, 6, 8, and 10. The schools taking part typically assigned a Liaison Officer to help us to collect the Consent Forms from students as they arrived back. We also visited many schools in the first week of Term IV to remind students to return their forms if they wished to participate in the study — this follow-up visit included a 2-3 minute school assembly address. Whilst there, we confirmed with the assigned Liaison Officer that a school teacher would be present at all times when we visited in Term IV. It was at this time that I booked an appointment with the school principal and other staff to complete the BAEW questionnaire.

Mr. Haywood and I were assigned to work in schools in the outer regions of Victoria since we did not have as many outside commitments as the other project team leaders (e.g. children) that required us to return to Geelong by close-of-business hours. As a result, we were often on the road for one to two weeks at a time, staying overnight in towns where the schools were located. It was common to drive up to eight hours in a hired van for a single school visit. This amount of travel required careful management in order to maximise the number of schools and students we could see. The high degree of travel also brought about many logistical challenges, such as ensuring that we stayed within budget, working around the needs of 20+ Research Assistants, and booking vehicles and accommodation far in advance.

Prior to any school visits, we had to ensure that we had all the required equipment and data collection tools, which I describe in more detail in the following sections. This equipment included:

- Printed copies of student questionnaires;
- Printed copies of Plain Language Statements;
- Printed copies of Consent Forms;

- Stadiometers;
- Weighing scales and a ceramic tile to place underneath for stability;
- Spare batteries;
- Pens and pencils; and,
- Fold-up screens to give the students privacy.

It was my responsibility as a project team leader to ensure that all these instruments were calibrated and ready for use upon arrival at the school.

5.5 Data collection in schools

The survey period took place in Term IV of the school year, between 7 October and 20 December 2013. We arrived at the school at least thirty minutes prior to the intended collection time in order to set-up an appropriate space for anthropometric measures (e.g. gym, assembly hall, a large classroom). An important feature of the space was privacy for the students when taking their weight and height measurements. Once we had cross-checked the names of students present with their signed Consent Forms (gathered by the assigned Liaison Officer), only then did we proceed. On average, a group of thirty children took approximately 60 minutes to collect their anthropometric measures (we usually had two stations running simultaneously).

We administered the behavioural questionnaires immediately after we collected the anthropometric data; however, at times it was difficult to get all the students together in the same place and arrange to have a teacher present to supervise, so this transition was occasionally delayed. I then stood at the front of the class while the Research Assistants handed-out copies of the questionnaire and pens. I reminded students to keep their answers private as we worked through the questionnaires. For a group of thirty children the behavioural questionnaires took about 30-40 minutes to complete (secondary students tended to finish more quickly).

After we finished collecting the student anthropometric and behavioural data, we handed-out fully-charged accelerometers to approximately every second student. As they were handed-out, we logged each student's name next to the accelerometer's serial number. We then left a pre-paid envelope with the administrative office so that they could be returned to Deakin University once the students had returned their accelerometers after seven full days. If we were able to time our run correctly, we returned to the school to collect the accelerometers in-person. We aimed to always do this because of the limited number of accelerometers and we needed to get them back as quickly as possible so that we could use them again in the next school.

5.6 Administration of measurement instruments

During the survey period, we followed a strict data collection protocol. We set-up stadiometers and scales in a quiet area within the school in an area where other students were unable to see the student being measured and weighed; a teacher would always observe. Research Assistants had completed training in how to collect these data types, but it was always my responsibility to check that all equipment was set-up and used properly. For example, I ensured that there were no gaps between parts of the stadiometer, that the scales read 0 kg before each use, and the stadiometer and scales were sat on a flat, firm surface. I also double-checked that participating students had handed-in a signed Consent Form before being measured.

Before a student was measured, they were asked to remove, whenever possible, all extra body (jackets) and head garments (hats) and their shoes and socks. I would keep a record of anything still worn in the hair (possibly for religious purposes) and any physical problems (e.g. broken leg or arm) that may impact us from getting an accurate measurement; students without an accurate measurement were later removed from final analysis. The student was asked to step onto the stadiometer and place their heels together with their shoulders and bottom touching the wall; we asked them to "stand tall like a soldier". The student then looked directly ahead with the lower border of their eye socket and the upper margin of the external opening of the auditory canal (ear hole) in the same horizontal line (refer to the Frankfurt Plane shown in Figure 5.3).

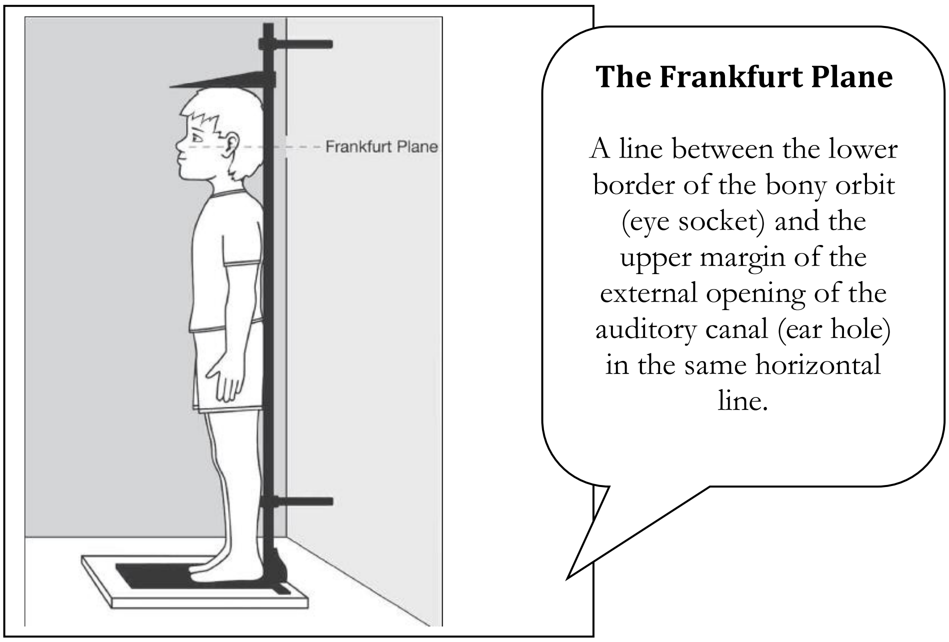


Figure 5.3. The Frankfurt Plane

Once the student was in position, I asked them to take a deep breath and stretch up tall, while keeping their heels together on the floor. I then took a measurement across the highest part of their head and brought down the movable headboard with sufficient pressure to compress their hair, while the student was still holding their breath. Finally, while still holding the headboard in place, I asked the student to breathe out and step away from the stadiometer. All measurements were recorded to the nearest 0.1 cm on a data collection template and the procedure was then repeated by a Research Assistant. If the two measures differed by more than 0.5 cm, we recorded a third measure using the same method and took the average.

Next, I asked the student to step in front of the scales; the scales were placed on a tile provided, or a nearby hard surface. I switched the scales on (typically with a soft kick on the button at the front of the scales) and changed the batteries if necessary. The student was asked to remove anything they had in their pockets, such as keys or other heavy items; I also asked them to remove any watches or jewellery. Following on from the height measurements, I ensured that the student was only wearing one layer of clothing. If the student, for example, was wearing a cultural garment (e.g. kaftan), I took note of this and their data were excluded from final analysis.

Finally, the student stood on the scales and looked straight ahead (i.e. not down at the reading); the student had their hands by their side. I would wait for the weight to stabilise on the monitor and I recorded their weight to the nearest 0.1 kg. The student then stepped off the scales and after the scales returned to zero, they repeated the procedure for a second reading. If the two readings were more than 0.5 kg apart, the process was repeated for a third reading. All three readings were recorded on a data collection template and I took the average.

Questionnaires

The CDQ and SHAPES questionnaires were stapled together and we administered both questionnaires in the same data collection period. The CDQ questionnaire was administered to students in the classroom at a specified time across the school day, or in the school gym or assembly hall. It was my responsibility to ensure beforehand that only students whose parents had given signed consent participated. The procedure we followed was to ask students to complete the CDQ immediately after they completed the SHAPES questionnaire. It was my role to explain and guide the students through to its completion. The CDQ took approximately ten minutes to complete and once it was completed, I checked to see if there were any incomplete or missing responses.

The SHAPES questionnaire was used to collect PA behavioural data. The questionnaire was typically administered to students at the same time as the CDQ questionnaire, so it was also completed in the classroom at a specified time across the school day (e.g. Period 4), or in the school gym or assembly hall with students spread out across the floor. It was my role to explain and guide the students through the SHAPES questionnaire until completion. The SHAPES questionnaire took approximately 15 minutes to complete and once it was done we checked to see if there were any incomplete or missing responses. If data were missing, I would ask the student to fill-in the empty responses.

Accelerometery

During the survey period, we handed out one ActiGraph GT3X or GT3X+ accelerometer per student to collect an objective measure of PA behaviour. As noted in Chapter Four, we were unable to source enough accelerometers to hand-out one accelerometer to every student who participated in the survey, so we applied a purposive sampling method and handed-out one to approximately every second student. Each student was given an accelerometer while they were having their anthropometric measures done and behind a screen — we made every effort to distribute the accelerometers evenly between boys and girls and we recorded a copy of the accelerometer's unique identifier on the sheet next to their name and weight measures. Students were instructed to wear the accelerometer on their right hip during waking hours for seven consecutive days, excluding in water-based and sparring activities (e.g. boxing). The student was instructed to then return the accelerometery to their teacher.

<u>School environment</u>

As noted in Chapter Four, the BAEW questionnaire was completed at the school-level, so there was no burden on the student population. It was an interview-led, semi-structured written questionnaire administered to 1-2 teachers (typically a Physical Education teacher), one member of the school food service, and the school principal or deputy principal. I would typically sit on one side of the table in a private meeting room, with the interviewees sitting next to each other on the other side. I would ask all of the questions and fill-in the consensus responses given by the interviewees. The BAEW questionnaire took approximately 20-30 minutes to complete.

5.7 Data security and storage

All data were transported as soon as possible to the secure offices at Deakin University. Individually-identifiable data (e.g. questionnaires, anthropometric logs) were kept in locked filing cabinets, while the Plain Language Statements and Consent Forms were kept in a separate locked cabinet. Data were dual-entered by two different members of the project leadership team and stored on password-protected computers at Deakin University. Individual names remained on the original stored file in order to exclude the student if they wished to withdraw from the study.

Once the data were entered and safely stored, a de-identified data set was extracted onto an encrypted memory stick, which I brought back to the University of Oxford (password-protected). The HTV Evaluation Steering Committee's policy was to store all data for seven years post-completion of the study (end-of-2020). These data will then be destroyed using the provisioned document destroying services within the University of Oxford. Furthermore, the WHOCC-OP has a system in place for the safe storage and disposal of research data should the principal investigators cease to be employed.

5.8 Preparation for statistical analysis

I approached the data set in four phases:

1) Run checks in search of any data entry error (a step repeated many times);
2) Create data types in preparation for statistical analysis;
3) Descriptive analysis; and,
4) Model building.

All four steps were completed using STATA IC 13.0. My descriptive results and the process I followed are presented in detail in Chapter Six, while my approach to the model building process is described in full in Chapter Seven. The descriptive statistics included a number of t-tests and simple regression models, while my findings from a number of logistic and multivariate regression models are presented in Chapter Seven. The following sub-sections describe how I created new data types in preparation for analysis.

<u>Student Body Mass Index z-scores</u>

In 2006, the WHO released an update on their child growth standards, as well as new commands for the most commonly used statistical packages ('zscore06' in STATA IC 13.0) that calculated anthropometric BMI z-scores in line with the updated 2006 WHO growth reference standards.[163] BMI z-scores are the deviation of an individual's (weight) value from the median value of a reference population, divided by the standard deviation of the reference population.[163] For population-based assessments, BMI z-scores are widely recognised as the leading system for analysis and presentation of anthropometric data.[164] The formula for calculating the BMI z-score is:

Z-score (or SD-score) = (observed value - median value of the reference population)
/ standard deviation value of reference population

Moreover, the WHO recommends that the following cut-off points be used to allow for greater generalisability of their BMI z-scores:

- Underweight (<-2.0 SD);
- Normal weight (-2.0 to 1.0 SD);
- Overweight (+1.0 to 2.0 SD); and,
- Obesity (+2.0 SD).

Student dietary behaviours

The Australian dietary guidelines (2013) recommended that children increase their daily intake of fruits and vegetables.[63] In preparation for statistical analysis, I used the CDQ self-report data to create two dichotomous variables that concerned the daily intake of fruit and the daily intake of vegetables (see Section 2.3.1.1). I assigned a 'Yes' (1) if the student met the recommended daily amount, and 'No' (0) if they did not.

In addition to looking at the achievement of Australian dietary guidelines, I created a diet quality index to provide a summary measure of overall diet quality. Using the data available from the CDQ, I adapted an index score in line with the Australian Healthy Eating Index (Aust-HEI) Score developed by the Australian Institute of Health and Welfare and based on Australian dietary guidelines.[165] The Aust-HEI Score represents a collection of scores applied to selected dietary components deemed to be representative of a healthy diet for Australian adults (I was not aware at the time of submission of a diet quality index score specifically for Australian children). The Aust-HEI focused on the daily consumption of food and consists of seven variables representing three dietary aspects: dietary variety, fruit and vegetable consumption, and fat (particularly saturated fat) consumption. These three elements have all been shown to be related to chronic disease risk.[165]

An important limitation to note is that the CDQ we used in the HTV survey did not collect data on one of the score components in the Aust-HEI Score: 'How often is the meat you eat trimmed of fat, either before or after cooking?' This component accounted for up to five points in the Aust-HEI's total score of 60 — so the adapted Aust-HEI I used in my later descriptive and regression analyses was out of a total score of 55. The other components that made the Aust-HEI Score were measures of variety, heathy choices, fruit and vegetable consumption, and consumption patterns associated with fat intake. Table 5.1 presents a summary of the diet quality index components included in my Aust-HEI Score. Despite the fact that the CDQ did not include the exact same list of questions used to develop the Aust-HEI components, the CDQ investigated many of the same core component areas.

Table 5.1. Summary of diet quality index components

Aust-HEI Component	Criterion	Minimum score	Maximum score
Measure of variety	Total number of foods eaten daily from five main groups: cereals, vegetables, fruit, meat, and dairy	0	10
Measure of healthy choice	Total number of unhealthy foods eaten daily: potato chips, biscuits, chocolate, and sweets	0	10
Fruit consumption	Two or more serves per day	0	10
Vegetable consumption	Four or more serves per day	0	10
Low-fat milk	Regularly consume plain milk, cheese, or plain yoghurt	0	5
Consumption of high-saturated 'junk' foods	Daily consumption of high-saturated fat, low nutrient density foods	0	10
Total		**0**	**55**

The Aust-HEI components had a maximum score out of 10 – except for 'Low-fat milk', which had a maximum score out of 5. The score for the daily consumption of each of the five food groups included in the 'variety' score was adjusted to be out of 2, with the overall score being the sum of these scores (out of 10). The measure for 'healthy' was an adjusted score for the daily consumption of unhealthy foods, with those eating the least scoring the highest (out of 10). The measure for 'fruit' was an adjusted score for the daily consumption of fruits, with those eating the recommended 2 or more serves scoring highest (out of 10). The measure for 'vegetable' was an adjusted score for the daily consumption of vegetables, with those eating the recommended 4 or more serves scoring highest (out of 10). The measure for 'milk' was an adjusted score for the daily consumption of plain milk, cheese, or plain yoghurt, with those eating the most plain dairy scoring the highest (out of 5). The measure for 'junk food' was an adjusted score for the daily consumption of high-saturated fat, low nutrient density foods, with those eating the least scoring the highest (out of 10).

Student physical activity behaviour

In line with the Australian national PA guidelines (2014) that recommended children aged 5-12 years participate in MVPA for ≥60 minutes each day, I used the data we collected from the SHAPES questionnaire to create a dichotomous PA variable.[85] Students were assigned a 'Yes' (1) if they met the daily recommended amount of PA, and 'No' (0) if they did not.

School Type and School Location

Using the BAEW questionnaire, I collected data related to the School Type and School Location. For statistical purposes, I created a categorical variable that described the School Type. As noted in Chapter Four, the primary schools included in the survey self-reported as either a Government, Private, or Independent school. I used this categorical variable in my analysis. Regarding the School Location, I created a dichotomous variable that classified schools as either Urban or Rural.

The ABS defines an urban area as those with 10,000 or more people within a defined geographical location.[166] The exception to this rule were "smaller" suburbs (less than 10,000 residents) within metropolitan Melbourne (e.g. Sunshine p/c 3020) or other major Victoria cities with a population of 50,000 or more, according to the latest available census data, which included the regional Victorian cities: Ballarat, Bendigo, Geelong, and Wodonga.

Socio-Economic Index for Areas score

For the purposes of my statistical analysis I created a variable to measure each student's socio-economic status. A lower SEIFA score indicated that an area was relatively disadvantaged compared to an area with a higher score.[162] The SEIFA score ranked LGAs around the state of Victoria according to relative socio-economic advantage and disadvantage, based on 2011 Australian Census data.[162] The score indicated the average socio-economic characteristics of the people, families, and households living in the area, commonly used to compare the relative socio-economic characteristics of areas at a given point in time.[162]

The SEIFA scores were calculated using individual-level postcodes, which was collected from the demographic information entered by students at the beginning of the behavioural questionnaires. An index score for a specific area was a weighted combination of Census (2011) variables for that area.[162] The scores for all Victorian LGAs were then standardised to a distribution where the mean equaled 1,000 and the SD was 100. To determine the rank of an area, the areas were ordered from the lowest score to the highest score.[162] The area with the lowest score was given a rank of one, the area with the second-lowest score was given a rank of two, and so on, up until the area with the highest score, which was given the highest rank. Finally, it is important to highlight that the SEIFA scores are an ordinal measure and so care should be taken when comparing scores. For example, an area with a score of 1,000 was not twice as advantaged as an area with a score of 500.[162]

Be Active Eat Well score

I constructed the 'BAEW Score' using the 33 unique questions described in Chapter Four — a score out of 33 to examine how many school environmental actions were in place promoting healthy eating and PA amongst students. I chose this method because my primary research question was concerned with the number of school environmental actions in place promoting healthy eating and PA. Because not all of the questions in the BAEW questionnaire comprised a "Yes" and "No" response option, some questions were dichotomised in order to create the BAEW Score (see Section 6.4). For example, if a response used a Likert scale (1. Very Good, 2. Good, 3. Moderate, 4. Bad, 5. Very Bad), the "most positive" answer(s) (i.e. 1. Very Good, and 2. Good) were grouped together to create a "Yes" (1) response, and the "not most positive" answer(s) (i.e. 3. Moderate, 4. Bad, 5. Very Bad) were grouped together to create a "No" (0) response. No school responded with the answer of "Unsure" for any of the 33 questions included in the BAEW questionnaire (see Appendix Three).

Furthermore, I created from using the BAEW Score two additional variables concerning the school food environment (Food Score) and the school PA environment (PA Score). The Food Score included 23 questions and the PA Score included eleven questions; Question No. 28 was related to both the Food and PA school environment and I included this question in both scores.

5.9 Summary of chapter

In this chapter, I presented an overview of my research project and described the data collection protocols we followed in the HTV evaluation survey. Pre-data collection, I helped to obtain ethics approval from multiple bodies. I co-developed the data collection protocols we followed during the survey period, as well as co-trained a team of 20+ Research Assistants. We successfully recruited at least one primary school and one secondary school across 26 different LGAs, visiting 50+ schools prior to, during, and following the completion of the HTV evaluation. When in the schools, I worked closely with the designated Liaison Officers and teachers to help collect the student anthropometric measures and self-reported behavioural data, together with the responses given by faculty staff about the school environment. I then described how I transformed these data into dependent and independent variables in preparation for analysis. The next chapter presents my descriptive findings.

- 6 -

RESULTS: Descriptive analysis

6.1 Outline of chapter

In this chapter, I present the descriptive data in my final sample. I begin with a description of my primary outcome variable, student zBMI, followed by a description of my secondary outcome variable, student MVPA accelerometery. I present a description of my primary exposure variable, drawn from the BAEW questionnaire, and separate these school-level variables by those that were most relevant to the school Food and PA environments.

6.2 Sample characteristics

Thirty-nine out of 156 invited primary schools (response rate [RR] = 25%) across 26 LGAs in Victoria agreed to participate in the HTV evaluation. From these schools, 856 students in Years 4 and 6 participated, with 3.3% self-reporting as Indigenous Australian. As stated in Chapter Five, my primary exposure variable was the school-level BAEW Score – derived from the BAEW questionnaire. Of the 39 primary schools that participated, only 35 completed the BAEW questionnaire. These included 27 Government, 7 Private, and 1 Independent school. No data were collected for non-respondent schools. One further school (Private) was excluded from analyses because it contained less than five students, which according to the ABS is potentially identifiable.[167]

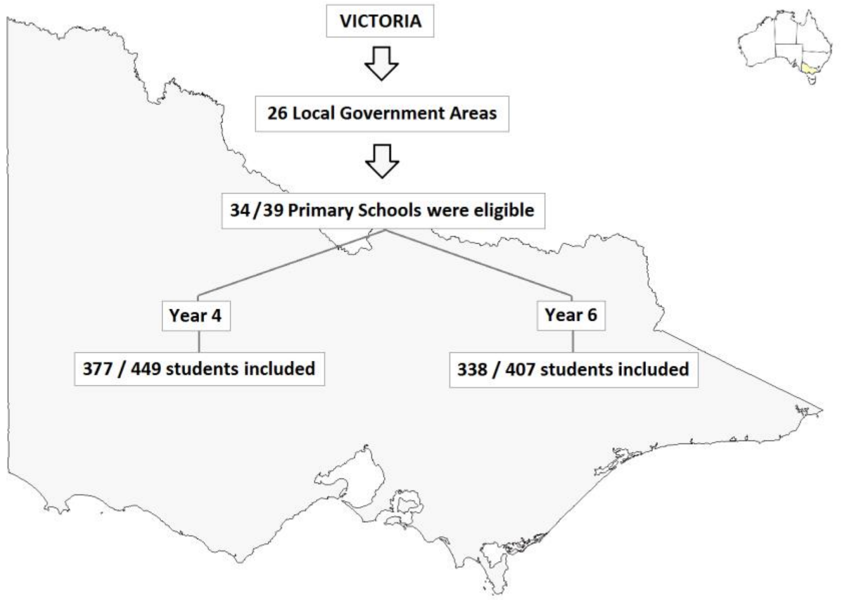


Figure 6.1. Survey results from the state of Victoria, Australia

A response rate of 32.97% of invited students agreed to participate in the HTV evaluation. No data were collected for non-respondent students. My final sample was reduced from 856 to **715 Year 4 and Year 6 students** (84% of total participating students) **across 34 primary schools** (89% of total participating schools) because five schools did not complete the BAEW questionnaire.

Table 6.1 shows the sample characteristics between the sample of students surveyed and the final sample used in my statistical analyses.

Table 6.1. Sample characteristics

Variable		Total surveyed (%) n = 856	Final sample (%) n = 715
Sex			
	Male	398 (46)	335 (47)
	Female	458 (54)	380 (53)
Age (years)			
	9	136 (16)	115 (16)
	10	300 (35)	253 (35)
	11	120 (14)	98 (14)
	12	286 (33)	240 (34)
	13	14 (2)	9 (1)
School Type			
	Government	660 (77)	523 (73)
	Private	133 (16)	169 (24)
	Independent	63 (7)	23 (3)
Year level			
	Year 4	449 (52)	377 (53)
	Year 6	407 (48)	338 (47)
Indigeneity ^			
	Non-Indigenous	781 (97)	679 (97)
	Indigenous	26 (3)	23 (3)

^49 students surveyed did not self-report their Indigenous Australian status

6.3 Primary outcome variable – student zBMI

My primary outcome variable, student zBMI, was constructed using WHO BMI growth reference standards and cut-points. Table 6.2 presents the distribution of weight status across Year 4 and 6 students.

Table 6.2. Weight status of students

Student zBMI	n = 715 (%)
Underweight (<-2.0 SD)	8 (1.1)
Normal (-2.0 to 1.0 SD)	483 (67.6)
Overweight (+1.0 to 2.0 SD)	156 (21.8)
Obese (+2.0 SD)	68 (9.5)

Student zBMI is presented at times as a categorical variable (using WHO cut-points), but this is solely to facilitate ease of comparison with other studies. I keep student zBMI as a continuous variable in regression models, which was done in order to capture the most amount of information in the data set. The distribution of student weight status before (BMI) and after transformation (zBMI) is presented in Figures 6.2 and 6.3; its distribution was skewed to the left due to the high prevalence of student O&O. Figure 6.3 shows a normal distribution of student zBMI.[168]

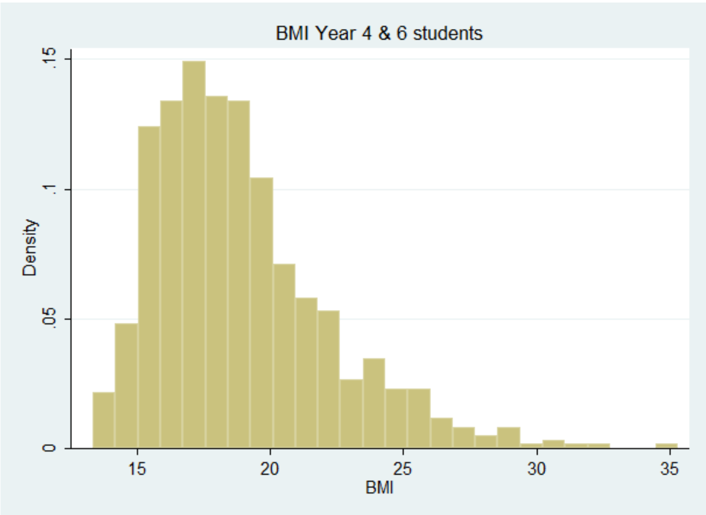


Figure 6.2. Histogram of student BMI (n = 715)

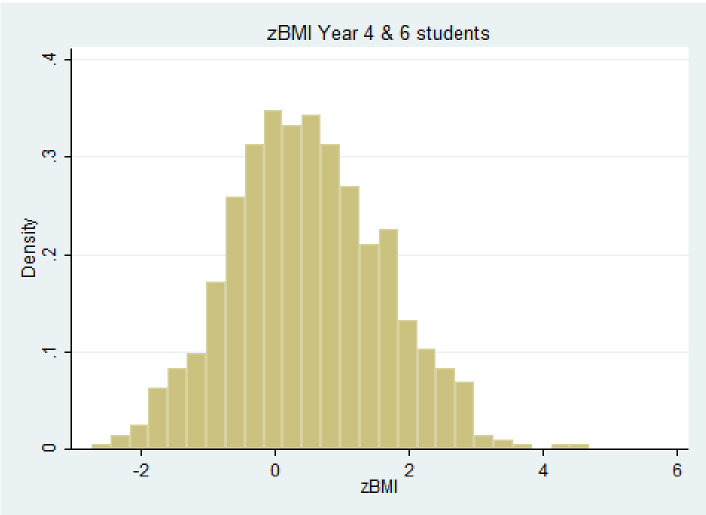


Figure 6.3. Histogram of student zBMI (WHO growth reference standards) (n = 715)

In total, 31.3% of primary school students were classified as O&O — well above the Australian average (25.0%).[15] Male students had a higher prevalence of O&O than female students (O&O 34.3% and O&O 28.7%, respectively) (t-test (713)=2.63, *p*-value = 0.008), so I separated male and female students in analyses. No statistically significant difference in mean zBMI was found between Year 4 and Year 6 students (t-test (713)=0.18, *p*-value = 0.859), thus I did not separate models by Year Level in order to increase the statistical power. A statistically significant difference was found in student zBMI between self-report Indigenous and non-Indigenous Australian students (t-test (713)=-3.85, *p*-value = 0.001). Table 6.3 shows mean student zBMI against the student-level variables.

Table 6.3. Mean zBMI against other student-level variables (*n* = 715)

Independent variable		*n* = 715 (%)	mean zBMI
Demographics			
Gender			
	Male	335 (46)	0.60
	Female	380 (54)	0.38
Age (years)			
	9	115 (16)	0.70
	10	253 (35)	0.43
	11	98 (14)	0.51
	12	240 (34)	0.44
	13	9 (1)	0.02
Indigeneity ^			
	Indigenous	23 (97)	1.30
	Non-Indigenous	679 (3)	0.45
School year			
	Year 4	377 (52)	0.49
	Year 6	338 (48)	0.47
SEIFA quintiles			
	1	201 (28)	0.53
	2	214 (30)	0.42
	3	125 (17)	0.73
	4	114 (20)	0.36
	5	31 (4)	0.18
Self-reported behaviours			
Daily Fruit Intake ^			
	*Met national guidelines**	652 (94)	0.47
	Did not meet national guidelines	45 (6)	0.63
Daily Vegetable Intake ^			
	*Met national guidelines**	268 (39)	0.47
	Did not meet national guidelines	425 (61)	0.48

Independent variable (cont.)	*n* = 715 (%)	mean zBMI
Daily amount of MVPA ^		
*Met national guidelines**	250 (43)	0.33
Did not meet national guidelines	328 (57)	0.52
Accelerometery		
Daily MVPA ^		
*Met national guidelines**	233 (91)	0.39
Did not meet national guidelines	24 (9)	0.75

MVPA = Moderate-to-Vigorous Physical Activity; zBMI = Body Mass Index z-scores; SEIFA = Socio-Economic Index for Areas.
^ 13 students did not report their Indigenous Australian status; 18 students did not report their Daily Intake of Fruit; 22 students did not report their Daily Intake of Vegetables; 137 students did not self-report their daily amount of MVPA; 458 students did not wear an accelerometer for 3 or more valid days of time-wear.
* Details of national guidelines presented in Chapter Five.

I found no statistically significant difference in mean zBMI between students who self-reported as meeting the Australian national guidelines for Daily Fruit Intake and those who did not (t-test (695)=0.89, *p*-value = 0.372). The same was also found for Daily Vegetable Intake (t-test (691)=0.13, *p*-value = 0.900). Mean zBMI between students who met the Australian guidelines for self-reported Daily MVPA and those who did not was on the cusp of being statistically significant (t-test (578)=1.92, *p*-value = 0.055). Using simple linear regression, I found no significant association between student zBMI and SEIFA quintiles (*F*(1,713)=0.65, *p*-value = 0.420).

6.3.1 Secondary outcome variable – MVPA accelerometery

My secondary outcome variable, student MVPA accelerometery, provided an objective measure to assess if students were meeting the recommended daily amount of MVPA (≥60 minutes). As shown in Table 6.3, the vast majority of students (91%) who wore an accelerometer for three or more valid days met the recommended daily amount of MVPA. We did not collect any data for non-respondents in the HTV evaluation, but I was able to compare the results between those students who wore an accelerometer and those who did not, together with those students who did not meet the inclusion criteria for accelerometery wear-time (see Table 6.5).

Table 6.4. Comparison of key findings between the sample of students who wore an accelerometer (*n* = 257), the students who did not meet the inclusion criteria (*n* = 68), and the rest of the sample (*n* = 390)

Variables	Accelerometery (%) *n* = 257	Accelerometery (%) (not met inclusion criteria) *n* = 68	Remainder of student sample *n* = 390
Primary outcome			
mean zBMI	0.43 (100)	0.59 (100)	0.50 (100)
Demographics			
Gender			
Male	112 (44)	37 (54)	186 (48)
Female	145 (56)	31 (46)	204 (52)
Age (years)			
9	35 (14)	10 (15)	70 (18)
10	97 (38)	24 (35)	132 (34)
11	37 (14)	5 (7)	56 (14)
12	85 (33)	27 (40)	128 (33)
13	3 (1)	2 (3)	4 (1)
Indigeneity ^			
Indigenous	7 (3)	3 (4)	13 (4)
Non-Indigenous	243 (97)	65 (96)	371 (96)
School year			
Year 4	137 (53)	34 (50)	206 (53)
Year 6	120 (47)	34 (50)	184 (47)
SEIFA quintiles			
1	74 (29)	15 (22)	112 (29)
2	77 (30)	22 (33)	115 (29)
3	32 (12)	16 (24)	77 (20)
4	60 (23)	14 (21)	70 (18)
5	14 (5)	1 (1)	16 (4)
Self-reported behaviours			
Daily Fruit Intake ^			
*Met national guidelines**	235 (93)	62 (91)	355 (94)
Did not meet national guidelines	17 (7)	6 (9)	22 (6)
Daily Vegetable Intake ^			
*Met national guidelines**	89 (35)	20 (29)	159 (43)
Did not meet national guidelines	164 (65)	48 (71)	213 (57)
Daily amount of MVPA ^			
*Met national guidelines**	90 (57)	35 (63)	139 (45)
Did not meet national guidelines	121 (43)	21 (38)	172 (55)

MVPA = Moderate-to-Vigorous Physical Activity; zBMI = Body Mass Index z-scores; SEIFA = Socio-Economic Index for Areas.
^ 13 students did not report their Indigenous Australian status; 18 students did not report their Daily Intake of Fruit; 22 students did not report their Daily Intake of Vegetables; 137 students did not self-report their daily amount of MVPA.
* Details of national guidelines presented in Chapter Five.

In the three groups of students described in Table 6.5, the lowest mean zBMI (0.43) was observed amongst students who wore an accelerometer for three or more valid days. Beyond this variation, few other differences were found between the three groups. With respect to the sample of students with valid accelerometery data, my statistical power was less in comparison to the sample collected for student zBMI.

Table 6.5. Proportion of students meeting recommended daily amount of MVPA as measured by accelerometery against other student-level variables (*n* = 257)

Independent variable	*n = 257* (%)	≥60min daily MVPA
Demographics		
Gender		
Male	112 (44)	96%
Female	145 (56)	88%
Age (years)		
9	35 (14)	91%
10	97 (38)	99%
11	37 (14)	89%
12	85 (33)	86%
13	3 (1)	67%
Indigeneity ^		
Indigenous	7 (3)	100%
Non-Indigenous	243 (97)	91%
School year		
Year 4	137 (53)	97%
Year 6	120 (47)	86%
SEIFA quintiles		
1	74 (29)	95%
2	77 (30)	89%
3	32 (12)	91%
4	60 (23)	90%
5	14 (5)	100%
Self-reported behaviours		
Daily Fruit Intake ^		
*Met national guidelines**	235 (93)	92%
Did not meet national guidelines	17 (7)	88%
Daily Vegetable Intake ^		
*Met national guidelines**	89 (35)	92%
Did not meet national guidelines	164 (65)	91%
Daily amount of MVPA ^		
*Met national guidelines**	90 (57)	96%
Did not meet national guidelines	121 (43)	88%

MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.
^ 7 students did not report their Indigenous Australian status; 5 students did not report their Daily Intake of Fruit; 4 students did not report their Daily Intake of Vegetables; 46 students did not self-report their daily amount of MVPA.
* Details of national guidelines presented in Chapter Five.

Table 6.6 shows that I still had enough statistical power to observe a number of significant differences between students who met the national recommendations of daily MVPA and those who did not. A significantly higher proportion of male students engaged in daily MVPA than females (X^2 = 5.598, *p*-value = 0.018). However, I did not separate my regression models by gender in order to increase statistical power, as the sample was already reduced from 715 to 257 students. For Indigenous Australian students, all students (100%) met the recommended daily amount of MVPA; however, the sample size was just seven. The students in Year 4 were much more active than students in Year 6 (X^2 = 10.784, *p*-value = 0.001). No statistically significant difference was found between the MVPA accelerometery and SEIFA quintiles (X^2 = 2.834, *p*-value = 0.586), self-report Daily Fruit Intake (X^2 = 0.281, *p*-value = 0.596), or Daily Vegetable Intake (X^2 = 0.034, *p*-value = 0.853).

6.4 Primary exposure variable – BAEW Score

My primary exposure variable, the BAEW Score, was created from the BAEW questionnaire, which was designed to examine how many school environmental actions (out of 33) were in place to promote healthy eating and PA amongst students. The bar-plot shown in Figure 6.4 presents the distribution of BAEW Scores.

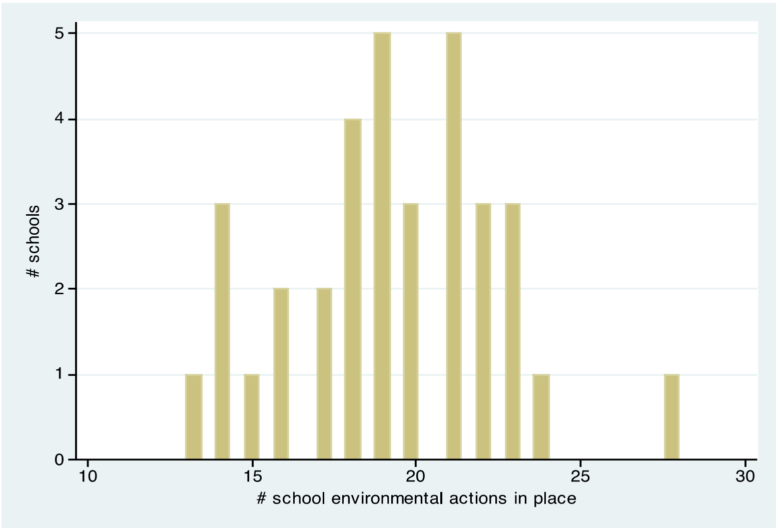


Figure 6.4. Bar-plot of BAEW Scores (0 - 33) across 34 primary schools

Primary schools had in place between 13 and 28 environmental actions to promote healthy eating and PA behaviours amongst students. The lowest possible score was zero and the highest was 33; I found a wide spread of BAEW Scores across the 34 schools, with a concentration around the mean (19.26) (SD = 3.29). Of the 33 questions included the BAEW Score, there was much variation amongst participating schools (see Table 6.7).

Table 6.6. School responses from using the BAEW Score (n = 34)

#	School environmental actions in place to promote healthy eating & PA amongst students	Number of schools by response (n = 34)	
		Yes (%)	***No (%)***
1.	Does your school have a written policy promoting healthy eating?	25 (74)	9 (26)
2.	Has your healthy eating policy been effective?	7 (21)	27 (79)
3.	Does the canteen routinely promote healthy food choices?	11 (32)	23 (68)
4.	Is the canteen food menu reviewed on a regular basis?	19 (56)	15 (44)
5.	Does your school have a written policy for types of foods sold by the foodservice?	14 (41)	20 (59)
6.	Are students allowed to eat in the classroom?	5 (15)	29 (85)
7.	Does your school have any events sponsored by soft drinks, fast food or confectionary companies?	7 (21)	27 (79)
8.	Does your school provide a breakfast service before school?	10 (29)	24 (71)
9.	Does your school provide copies of healthy eating and physical activity policies to parents?	23 (68)	11 (32)
10.	Do you have a written policy promoting physical activity?	27 (79)	7 (21)
11.	Does your school have two or more hours of formal physical education per week?	19 (56)	15 (44)
12.	Does your school have an effective policy to reduce local traffic congestion?	17 (50)	17 (50)
13.	Does your school have an effective student pedestrian safety program?	19 (56)	15 (44)
14.	Does your school have an effective cycling safety program?	16 (47)	18 (53)
15.	Does your school have a pricing policy to encourage the sale of healthy foods?	8 (24)	26 (76)
16.	Is making a profit an important part of the school foodservice?	32 (94)	2 (6)
17.	Do your teachers act as role models for physical activity?	2 (6)	32 (94)
18.	Do your teachers act as role models for healthy eating?	28 (82)	6 (18)
19.	Would you rate the nutritional value of the food you sell as high?	19 (56)	15 (44)
20.	Is fruit available by the school foodservice?	20 (59)	14 (41)
21.	Is low-fat milk available by the school foodservice?	27 (79)	7 (21)
22.	Is low-fat yoghurt available by the school foodservice?	28 (82)	6 (18)
23.	Are filled rolls/ sandwiches available by the school foodservice?	26 (76)	8 (24)
24.	Are lollies/ sweets available by the school foodservice?	31 (91)	3 (9)
25.	Are hot chips available by the school foodservice?	30 (88)	4 (12)
26.	Are energy/ sugary drinks available by the school foodservice?	33 (97)	1 (3)
27.	Are crisps available by the school foodservice?	24 (71)	10 (29)
28.	Are hot pies available by the school foodservice?	9 (26)	25 (74)
29.	Does your school have a vegetable garden?	30 (88)	4 (12)
30.	Is your indoor play area adequate?	26 (76)	8 (24)
31.	Is your outdoor play area adequate?	31 (91)	3 (9)
32.	Is your available sporting equipment adequate?	31 (91)	3 (9)
33.	Does your school have an effective cycle storage facility?	23 (68)	11 (32)

In line with my primary research question, my hypothesis was that student zBMI would be significantly associated with the number of school-level environmental actions in place to promote healthy eating and PA amongst students. From first observations in the box-plot shown in Figure 6.5, student zBMI did not appear to be associated with the BAEW Score.

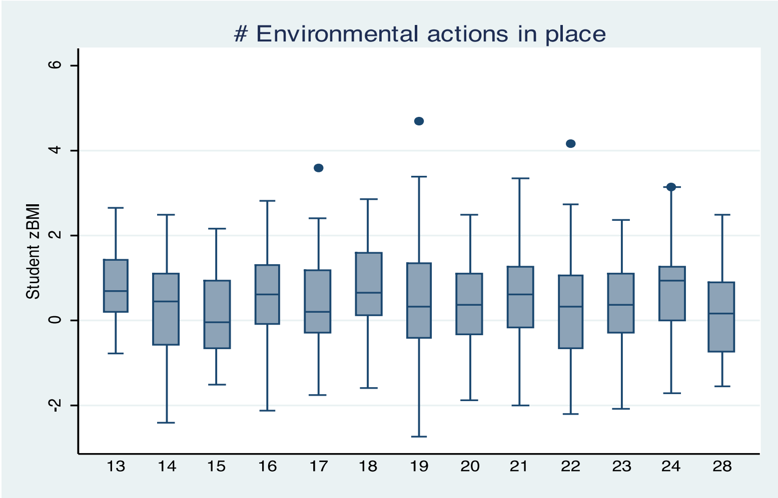


Figure 6.5. Box plot of student zBMI by BAEW Score

Using simple linear regression, I found no significant association between student zBMI and the BAEW Score ($F(1,713)=0.07$, p-value = 0.790). I then transformed the BAEW Score into a binary variable to test if this had any effect — I separated the BAEW Scores at either side of the mean (19.26). Schools that scored between zero and 19 (54.97%) were labeled as 'BAEW Low', and schools that scored between 20 and 33 (45.03%) were labeled as 'BAEW High'. I found no statistically significant association between student zBMI and the dichotomised version of the BAEW Score (t-test (713)=0.822, p-value = 0.935).

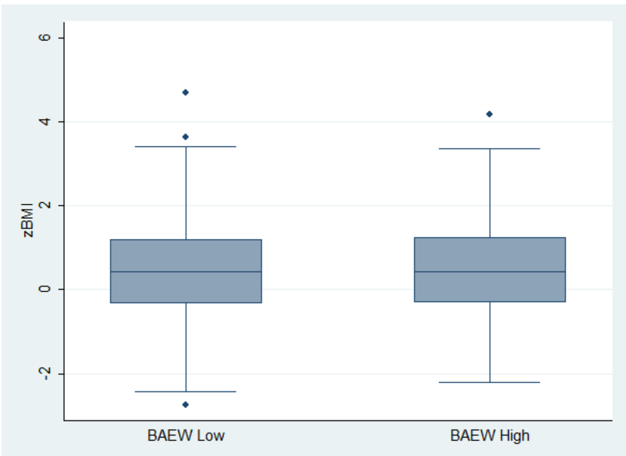


Figure 6.6. Box plot of student zBMI by dichotomised BAEW Score

No significant association was observed between student MVPA accelerometery and the BAEW Score (X^2 = 8.722, p-value = 0.726) or its dichotomised transformation (X^2 = 0.033, p-value = 0.856). The next step was to separate the BAEW Score by the questions that related most to the school Food environment and to the school PA environment.

6.4.1 Food Score

The scores related to the school Food environment ranged between nine and 20 (out of 23) environmental actions in place to promote healthy eating amongst students. It was important to find this variation for statistical purposes, with the scores concentrated around the mean (13.05) (SD = 2.41) (see Figure 6.7).

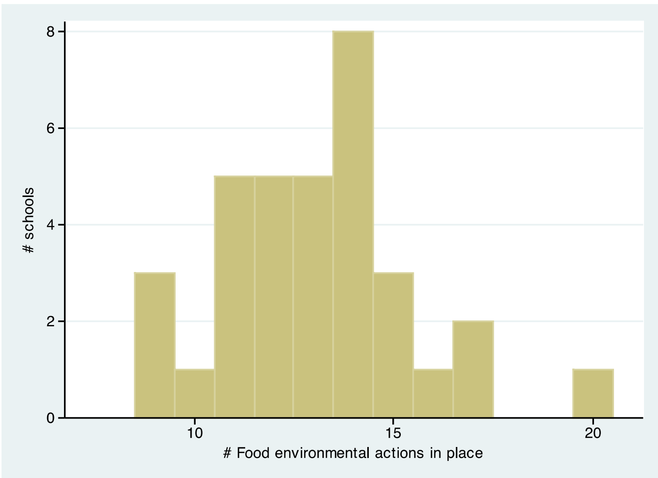


Figure 6.7. Bar-plot of Food score (out of 23)

There was no statistical association between student zBMI and the Food Score (F(1,713)=1.33, p-value = 0.249); the same was found between student MVPA accelerometery and the Food Score (F(1,255)=0.06, p-value = 0.813).

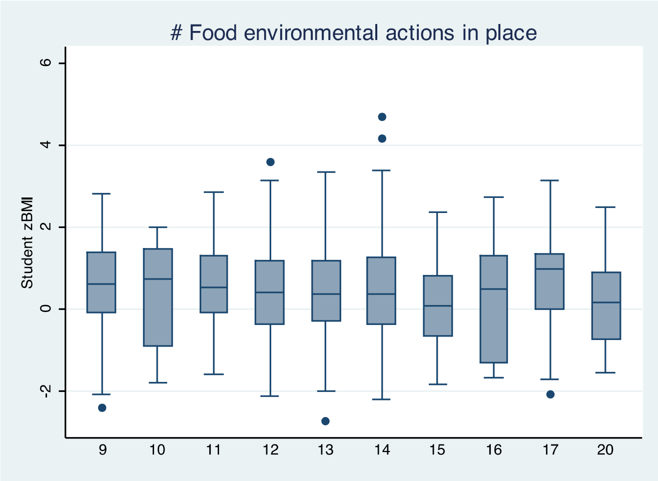


Figure 6.8. Box plot of student zBMI by Food Score

6.4.2 PA Score

The scores related to the school PA environment ranged between three and nine (out of eleven) environmental actions in place to promote PA amongst students. The scores were skewed to the right and reported a smaller range of scores (mean 6.88; SD = 1.90) than observed using the Food Score. There was no statistical association between student zBMI and the PA Score (F(1,713)=0.74, p-value = 0.388); the same was found between student MVPA accelerometery and the PA Score (F(1,251)=0.03, p-value = 0.854).

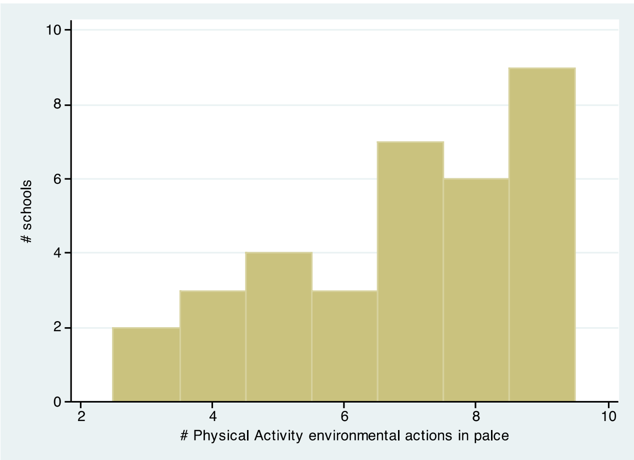


Figure 6.9. Bar-plot of PA score (out of 11)

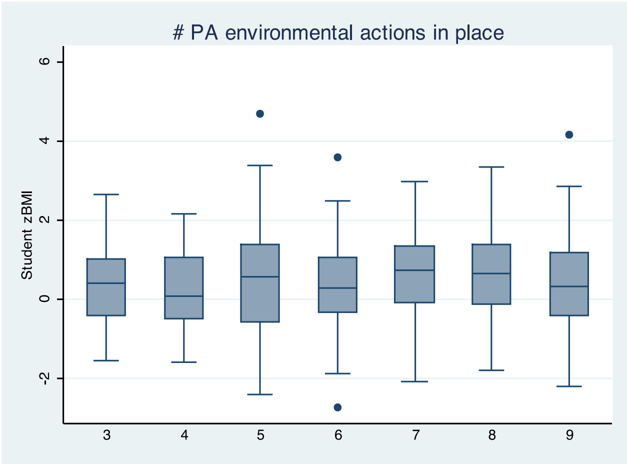


Figure 6.10. Box plot of student zBMI by PA Score

6.5 Independent variables

As many later regression models were separated by gender, it was important to check if student zBMI was normally distributed for both male and female students, which is shown in Figures 6.11 and 6.12.

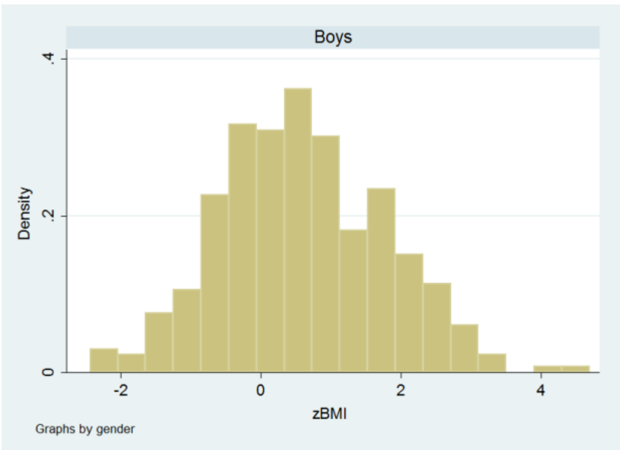


Figure 6.11. Histogram of student zBMI by males (*n* = 335)

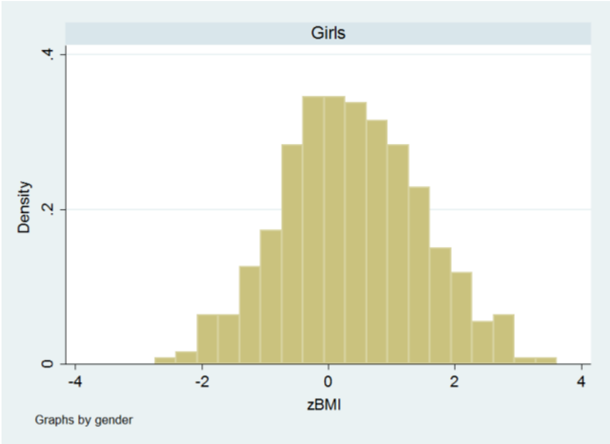


Figure 6.12. Histogram of student zBMI by females (*n* = 380)

Student zBMI was not statistically associated with SEIFA quintiles (see Figure 6.13). I found no significant difference between male and females with regards to SEIFA quintiles (X^2 = 4.713, *p*-value = 0.318); a SEIFA score of '1' represented the communities of greatest disadvantage.

Table 6.7. Student gender by SEIFA quintiles

SEIFA quintile	Male	Female
1	103 (31%)	98 (26%)
2	90 (27%)	124 (33%)
3	59 (18%)	66 (17%)
4	71 (21%)	73 (19%)
5	12 (4%)	19 (5%)
Total	335	380

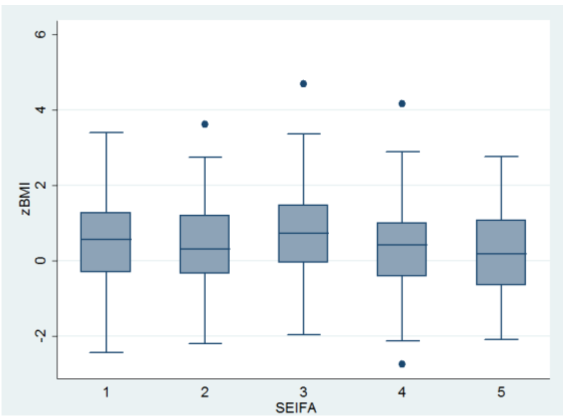


Figure 6.13. Box-plot of student zBMI by SEIFA quintiles

Gender was significantly associated with student Daily Fruit Intake (X^2 = 4.355, *p*-value = 0.037) and self-report Daily MVPA (X^2 = 16.882, *p*-value = 0.000), which gave further reason to separate regression analyses by gender. Daily Vegetable Intake (X^2 = 0.422, *p*-value = 0.837), however, was not significantly associated with gender. Students who self-reported as Indigenous Australian were a recognised at-risk group for poor health outcomes and residing in lower socio-economic areas.[67] However, the 23 Indigenous students included in my final sample were not significantly associated with the SEIFA quintiles (X^2 = 2.574, *p*-value = 0.631).

Self-reported Daily MVPA

The sample was reduced for students who self-reported their daily amount of MVPA (*n* = 578). Daily MVPA was significantly associated with a number of other independent variables, as well as closely associated with student zBMI. Daily MVPA differed significantly between male and female students (X^2 = 16.882, *p*-value = 0.000) and between Indigenous and non-Indigenous students (X^2 = 9.340, *p*-value = 0.002). Students in Years 4 and 6 differed significantly in their daily amount of MVPA (X^2 = 29.367, *p*-value = 0.000), as did students who ate the recommended daily amount of vegetables (X^2 = 24.040, *p*-value = 0.000).

Table 6.8. Student self-report Daily MVPA by gender (*n* = 578)

Dietary variables	Males	Females	Total
Met guidelines for Daily MVPA^	146 (52%)	104 (35%)	250 (43)
Did Not Meet guidelines for Daily MVPA^	135 (48%)	193 (65%)	328 (57)
Total	281 (49%)	297 (51%)	578

^ 137 students did not self-report their daily amount of MVPA

Self-reported daily MVPA and MVPA accelerometery

A total of 211 students presented MVPA data by self-report and accelerometery; a total of 137 students did not self-report their daily MVPA and 458 did not present valid accelerometery data. The self-report MVPA data was a binomial variable (did meet / did not meet Australian PA guidelines), while the MVPA accelerometery data could be used as a binomial (did meet / did not meet Australian PA guidelines) or a continuous variable (count of MVPA minutes per day). Table 6.9 presents a two-by-two of self-report MVPA data and MVPA accelerometery data.

Table 6.9. Self-report MVPA vs MVPA accelerometery

	Self-report MVPA -	Self-report MVPA +	Total
MVPA accelerometery -	14 (78%)	4 (22%)	18 (9)
MVPA accelerometery +	107 (55%)	86 (45%)	193 (91)
Total	121 (57%)	90 (43%)	211

+ = met Australian PA guidelines for daily MVPA
- = did not meet Australian PA guidelines for daily MVPA

Ninety-one per cent of students who wore an accelerometer were found to meet the Australian PA guidelines for daily MVPA; this meant that there was little variation in the accelerometery data set. Using a Chi-squared test, there was not a statistically significant association between self-report MVPA and MVPA accelerometery ($X^2 = 3.359$, *p*-value = 0.067). Using a t-test and keeping MVPA accelerometery as a continuous variable, I did not find a statistically significant association between MVPA accelerometery and self-report MVPA (t-test (209)=-1.675, *p*-value = 0.096). Despite both variables examining daily MVPA in students, I found that these two variables were not statistically associated and as such I chose to use both measures in later regression analyses.

School Type and School Location

Together with the BAEW questionnaire, we collected school-level data on the School Type (Government, Private, or Independent) and the School Location (Urban or Rural). Table 6.10. shows the descriptive findings between these school-level variables and student zBMI and MVPA accelerometery. I found no significant association between student zBMI and the School Type ($F(1,713)=0.74$, p-value = 0.391) or School Location (t-test (713)=-0.387, p-value = 0.699); the same was observed between student MVPA accelerometery and School Type (X^2 = 0.753 p-value = 0.686) and School Location (X^2 = 1.735, p-value = 0.188).

Table 6.10. Independent variables by student zBMI (n = 715) and MVPA accelerometery (n = 257)

	Student zBMI		MVPA accelerometery	
Independent variable	***n* (%)**	**Mean zBMI**	***n* (%)**	**≥60min daily MVPA**
School Type				
Government	523 (73)	0.52	201 (78)	93%
Private	169 (24)	0.44	49 (19)	90%
Independent	23 (3)	0.35	7 (3)	86%
School Location				
Urban	447 (63)	0.47	136 (53)	89%
Rural	268 (37)	0.50	121 (47)	94%

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity.

The BAEW Score was not significantly associated with School Type ($F(1,31)=3.66$, p-value = 0.065). There was no statistical difference in BAEW Scores between Urban and Rural schools ($F(1,31)=2.42$, p-value = 0.130).

Aust-HEI scores

The average score for the Aust-HEI was 34 out of 55 (62%). There was not a significance difference in the Aust-HEI Scores between male and female students (t-test (643)=-0.810, *p*-value = 0.418). Using Pearson's correlation (*r*), I did not find a significant association between student zBMI and the Aust-HEI Score (*r*(643) = 0.029, *p*-value = 0.461). At the end of Chapter 7, I present the results from my regression analysis using the Aust-HEI instead of measures for the daily intake of fruits and vegetables.

Table 6.11. Mean and median scores for Aust-HEI (out of 55) and components (out of 10)

Variable	Males (*n* = 311)		Females (*n* = 354)		All (*n* = 665)	
	Mean	Median	Mean	Median	Mean	Median
Aust-HEI Score	34.1	35	34.4	35	34.3	35
Variety	5.5	5	5.3	5	5.4	5
Healthy choice	3.5	4	3.8	4	3.7	4
Fruit intake	8.4	9	8.7	9	8.6	9
Vegetable intake	5.9	6	6.1	6	6.0	6
Plain milk (5)	2.4	2	2.3	2	2.3	2
Junk food intake	8.3	8	8.3	8	8.3	8

6.6 Summary of chapter

The majority of primary schools, as well as students from Year 4 and 6, chose not to participate in the HTV evaluation — just 33% of invited students took part. Included in my final sample of 715 students, 23 self-identified as an Indigenous Australian — a high-risk group for childhood obesity and other poor health outcomes. My student BMI data were skewed, so I logged them in accordance with WHO growth reference standards. A higher proportion of male students were O&O; male (34.3%) and female (28.7%) students were both above the national average of 25.0%. Despite the small sample size, mean zBMI was significantly higher amongst Indigenous Australians (1.30) than non-Indigenous students (0.45). From the 257 students who provided valid accelerometery data, I found that the Year 4 students (97% met MVPA guidelines) were significantly more active than students in Year 6 (86%). Mean zBMI was also lowest among students who wore an accelerometer for three or more valid days (0.43) in comparison to those who did not meet the inclusion criteria (0.59) or were not assigned an accelerometer (0.50). Student self-report daily MVPA was significantly associated with a number of variables, including: student zBMI, Gender, Year Level, MVPA accelerometery, and Daily Vegetable Intake. My descriptive analysis did not indicate a strong association between student weight-related factors and the school environment.

- 7 -

RESULTS: Model building

7.1 Outline of chapter

In this chapter, I build on my descriptive results and investigate further the associations between student zBMI and MVPA accelerometery and the school-level promotion of healthy eating and PA. I first present a full example of the model building process, which aimed to answer my primary research question. This is followed by a presentation of the results from other regression models using the same approach to model building, including for my secondary outcome variable: student MVPA accelerometery. A discussion of my results, highlighting their limitations and implications for future research, is presented in Chapter Eight.

7.2 Answering my primary research question

My primary research question concerned the association between student zBMI and the BAEW Score. The appropriate statistical test for this type of analysis was multivariate regression, which uses one continuous dependent variable and two or more independent variables (categorical and/or continuous). I followed the model building process as outlined in Chapter Five. All statistical tests were conducted using STATA IC 13.0.[169]

The data types included in my analysis are shown in Table 7.1. Because of the significant differences in mean zBMI, all regression models were separated between male and female students. A full example of the model building process – concerning male students – is presented in the following section. The primary outcome variable was student zBMI. The independent variables were: the BAEW Score, School Location, School Type, self-report Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, and SEIFA quintiles. Analysis of the MVPA accelerometery data set is presented at the conclusion of this chapter.

Table 7.1. Description of data types

Variable	Data type	Description
Student zBMI	Continuous	Student BMI z-score
BAEW Score	Continuous	Number of school-level actions in place to promote healthy eating and physical activity (out of 33)
School Location	Binomial	Urban / Rural
School Type	Categorical	Government / Private / Independent
Daily Fruit Intake	Binomial	Self-reported as meeting national guidelines for daily fruit intake / did not meet national guidelines
Daily Vegetable Intake	Binomial	Self-reported as meeting national guidelines for daily vegetable intake / did not meet national guidelines
Daily MVPA	Binomial	Self-reported as meeting national guidelines for daily MVPA / did not meet national guidelines
SEIFA quintiles	Categorical	Resides in area of disadvantage to advantage (ordinal scale 1-5)
Accelerometery MVPA	Binomial	60 minutes or more of daily MVPA as measured by accelerometery / less than 60 minutes per day

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; BAEW = Be Active Eat Well questionnaire; SEIFA = Socio-Economic Index for Areas.

The first step in the model building process was to run an unadjusted multivariate regression model, without checking for any of the underlying assumptions. The final sample of students was reduced to 277 males because a portion of students did not report their Daily Fruit Intake (6), Daily Vegetable Intake (5), or Daily MVPA (47). The unadjusted multivariable regression model shown in Table 7.2 did not report a significant association between student zBMI and the BAEW Score. However, student Daily MVPA was significantly associated with student zBMI (*p*-value = 0.004).

Table 7.2. Unadjusted multivariable regression model between student zBMI (n = 277 males) and BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles

Variable	Coefficient	Std. Error	*p*-value
Constant	1.077	0.662	0.105
BAEW Score	-0.007	0.026	0.781
School Location	-0.084	0.154	0.588
School Type			
Private	-0.059	0.206	0.775
Independent	0.025	0.440	0.954
Daily Fruit Intake	0.070	0.274	0.798
Daily Vegetable Intake	-0.096	0.151	0.523
Daily MVPA	-0.420	0.145	**0.004**
SEIFA quintiles			
2	-0.268	0.213	0.209
3	0.081	0.230	0.724
4	-0.265	0.226	0.242
5	-0.222	0.379	0.558

Number of Obsv.	277 males
F-statistic	1.29
p-value	0.232
R-squared	0.051

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

Before these results could be confirmed, however, I needed to perform a number of statistical tests to examine the underlying assumptions of the model. As a first means of identifying outliers, I examined the studentized residuals, which are a type of standardized residual that is commonly used to identify outliers, with residuals presented using a stem and leaf plot.

```
-2** | 55,45
-2** | 22
-2** | 19,14,05,00
-1** | 96,93,81,80
-1** | 66,65,63
-1** | 51,46,41,41,40,40
-1** | 39,38,38,35,32,26,25,25,24,22,22,21
-1** | 17,16,15,10,08,07,02,00
-0** | 99,98,96,93,91,90,89,89,89,88,86,86,83,83,81,80
-0** | 79,79,78,77,75,74,73,72,71,71,70,70,70,69,68,67,63,62,61,60,60
-0** | 58,58,58,58,58,56,56,55,55,55,52,52,51,51,49,49,46,46,46,45,44
-0** | 39,38,38,37,37,36,36,36,35,35,35,34,34,32,31,31,30,29,29,27, ... (25)
-0** | 19,18,17,17,15,14,12,12,11,11,11,09,08,07,05,05,04,02,01,01
 0** | 00,00,02,03,03,04,05,06,06,07,08,09,09,09,10,10,11,11,11,12,14,19
 0** | 20,21,22,24,24,26,29,30,30,31,31,31,33,35,35,36
 0** | 40,41,41,41,42,42,42,42,44,44,44,45,46,48,48,48,48,49,50,51, ... (24)
 0** | 60,63,64,67,67,67,67,69,72,73,74,75
 0** | 80,80,82,82,84,85,85,86,90,94,96,99
 1** | 01,02,02,03,05,05,08,11,15,15,18
 1** | 20,22,23,27,28,30,32,32,36,37
 1** | 41,42,42,46,54,55,55,55,56,57
 1** | 60,60,67,69,70,75,77
 1** | 80,93,99,99
 2** | 09,14,15,19
 2** |
 2** |
 2** |
 2** |
 3** |
 3** |
 3** | 40,44
```

Figure 7.1. Stem and leaf plot of studentized residuals (n = 277 males)

Studentized residuals that exceeded +2 or -2 were cause for concern as potential outliers, with greater concern given to those that exceeded +2.5 or -2.5, and even more at +3.0 or -3.0. Using STATA IC 13.0, I sorted these data on their residuals and showed the ten largest and ten smallest residuals, along with their Unique ID and LGA. CAT06A004 (-2.56), CAT06A002 (-2.45) and BPN0603 (-2.22) were at this stage the most worrisome observations, with seven others also of concern. I then listed the studentized residuals against the variables included in the unadjusted model to check for data entry errors, but no data entry error was found. I return to these potential outliers later in the model building process.

I next looked at the leverage of observations to identify any observations that could have influence on my regression coefficient estimates. Common practice was to give careful examination to any observations with leverage greater than **(2k+2)/n** — here, **k** was the number of independent variables and **n** was the number of observations, i.e. (2x7+2)/277 = 0.0578.

```
. list lev id bmiz_who if lev >.05776173
```

	lev	id	bmiz_who
238.	.0606412	STM04A018	-1.72
239.	.0611233	STM06A007	-.35
240.	.0668092	TR436A05	-.31
241.	.0675742	NBK04A003	.33
242.	.068306	SP4MMM03	-.98
243.	.0687219	MEL04H006	2.43
244.	.068727	LPS0414	2.89
245.	.0698359	MAN06A009	.4
246.	.0703382	MUR06004	.21
247.	.0710007	TSPS04004	-.46
248.	.071279	PSPS42005	-.15
249.	.071279	PSPM38001	1.04
250.	.0713093	BW056C002	1.79
251.	.0714911	NBK04A002	-.76
252.	.0762072	FPS60D006	1.69
253.	.0832656	SP4MLJ05	4.69
254.	.0833038	WPS603	.41
255.	.0852201	OLP06A007	-.47
256.	.0861885	CAT04B006	2.12
257.	.0861885	CAT06A002	-2.07
258.	.0880336	BW034B004	0
259.	.0963629	BW056C001	-2.08
260.	.09696	TR436E08	2.76
261.	.0984792	MPS402	-.53
262.	.1002138	SPS06009	.58
263.	.1027098	BUPS0401	2.38
264.	.1027098	BUPS0603	-.13
265.	.1044059	BUPS0403	.27
266.	.1056231	TR436H02	1.16
267.	.1088977	BPN0606	-1.35
268.	.1299275	OLRPS0412	-.69
269.	.1375708	STPS06010	1.49
270.	.140556	STPS06011	2.02
271.	.1409324	STPS06007	-1.55
272.	.1409324	STPS06004	-.59
273.	.1411693	NBK04B005	1.07
274.	.1438462	STPS06008	1.74
275.	.1560837	STPS06002	.75
276.	.1844994	STPS06001	1.66
277.	.1847452	STPS06006	-.93

Figure 7.2. Leverage of observations in unadjusted multivariate regression model

I found a number of observations above the 0.0578 threshold that required closer inspection (see Figure 7.2). All students from the Independent school had large leverage; there was only one Independent school that participated in the HTV evaluation. CAT06A002 (0.0862) – which had large residuals and was earmarked as a potential outlier – had large leverage. Several other observations also warranted closer inspection; however, none were found to be the result of data entry error.

I next created a plot that showed the leverage by the residual squared. This looked for observations that were jointly high on both measures. Using residual squared instead of residual itself, the leverage by residual squared plot was restricted to the first quadrant and the relative positions of data points were preserved; this allowed me to check for potential influential observations and outliers at the same time (see Figure 7.3).

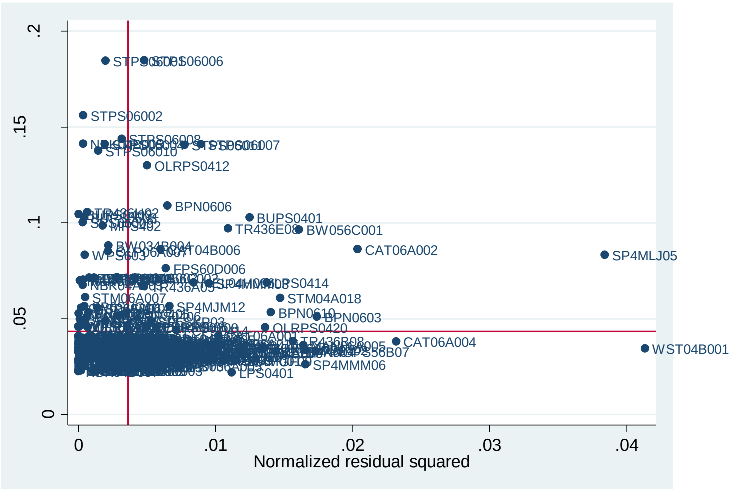


Figure 7.3. Graph of leverage by residual squared

The two reference lines in Figure 7.3 are the means for leverage (horizontal) and for the normalised residual squared (vertical). The points that needed to be monitored were the grouping of students from the Independent school (which had large leverage) and SP4MLJ05 (which had large residual squared) and WST04B001.

Next, I tested for overall measures of influence. Cook's D is commonly used to measure influence, which combines information on the residual and the leverage.[168] The lowest value that Cook's D can assume was zero and the higher the value the more influential it was; the conventional cut-off is **4/n** (i.e. 4/277).

```
. list d id bmiz_who score location school_types fruitADG vegADG MVPAwk seifa_quint if d>4/277
```

	d	id	bmiz_who	score	location	school_ty~s	fruitADG	vegADG	MVPAwk	seifa_quint
259.	.0147132	MEL04H006	2.43	17	Urban	Government	Did Not Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 3 and 4
260.	.0149864	OLRPS0420	-1.51	15	Urban	Catholic	Did Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 7 and 8
261.	.0165579	SP4MMM03	-.98	19	Urban	Catholic	Did Not Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 1 and 2
262.	.0184606	BPN0610	2.51	28	Urban	Government	Did Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 3 and 4
263.	.0190476	OLRPS0412	-.69	15	Urban	Catholic	Did Meet ADG	Did Meet ADG	-60min MVPA	deciles 9 and 10
264.	.0197102	BPN0606	-1.35	28	Urban	Government	Did Not Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 7 and 8
265.	.0210251	CAT06A004	-2.43	14	Urban	Catholic	Did Meet ADG	Did Meet ADG	+60min MVPA	deciles 1 and 2
266.	.0217315	BPN0603	-1.57	28	Urban	Government	Did Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 1 and 2
267.	.0223433	STM04A018	-1.72	20	Rural	Catholic	Did Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 3 and 4
268.	.0240581	LPS0414	2.89	21	Urban	Government	Did Not Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 7 and 8
269.	.0286726	TR436E08	2.76	21	Urban	Government	Did Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 9 and 10
270.	.0295098	STPS06006	-.93	19	Urban	Independent	Did Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 9 and 10
271.	.0325432	STPS06011	2.02	19	Urban	Independent	Did Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 3 and 4
272.	.0336334	WST04B001	4.17	22	Urban	Government	Did Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 7 and 8
273.	.0352071	BUPS0401	2.38	23	Rural	Government	Did Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 9 and 10
274.	.0376343	STPS06007	-1.55	19	Urban	Independent	Did Meet ADG	Did Meet ADG	+60min MVPA	deciles 3 and 4
275.	.0419485	BW056C001	-2.08	23	Urban	Government	Did Meet ADG	Did Not Meet ADG	+60min MVPA	deciles 9 and 10
276.	.0464396	CAT06A002	-2.07	14	Urban	Catholic	Did Not Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 3 and 4
277.	.084011	SP4MLJ05	4.69	19	Urban	Catholic	Did Not Meet ADG	Did Not Meet ADG	-60min MVPA	deciles 5 and 6

Figure 7.4. Cook's D for observations with large leverage and large residual squared

As shown in Figure 7.4, the Cook's D for SP4MLJ05 was by far the largest, with several Independent school students again of concern. Cook's D is a commonly used measure of influence, but it was important that I gave consideration to other more specific measures of influence to assess how each coefficient changed when others were deleted. Using STATA IC 13.0, I created DFBETA values for each independent variable; each beginning with the letters DF. The outcome was eight new variables: _dfbeta_1 (BAEW Score), _dfbeta_2 (School Location), _dfbeta_3 (School Type [Private]), _dfbeta_4 (School Type [Independent]), _dfbeta_5 (Daily Fruit Intake), _dfbeta_6 (Daily Vegetable Intake), _dfbeta_7 (Daily MVPA), _dfbeta_8 (SEIFA quintiles). As shown in Figure 7.5, The first value listed for _dfbeta_1 was 0.28, which meant that by including it in my analysis (as compared to being excluded) it increased the coefficient for the BAEW Score by 0.28 standard errors.

```
. list id _dfbeta_1 _dfbeta_2 _dfbeta_3 _dfbeta_4 _dfbeta_5 _dfbeta_6 _dfbeta_7 _dfbeta_8 in 1/5
```

	id	_dfbeta_1	_dfbeta_2	_dfbeta_3	_dfbeta_4	_dfbeta_5	_dfbeta_6	_dfbeta_7	_dfbeta_8
1.	CAT06A004	.2809598	.2278081	-.063729	.0432644	.0154335	-.1363892	-.1433896	.1284675
2.	CAT06A002	.2148946	.1479166	-.2378592	.05708	.502477	.0143176	.070833	-.2724575
3.	BPN0603	-.3305745	.0159624	.0713341	-.0128305	-.0486201	.1049219	.1407697	.2050622
4.	BW056C001	-.0567636	.096601	-.0081205	.149574	-.0672168	.1266092	-.1352153	-.009752
5.	MAN06A005	.1369357	-.1065801	.2328956	.0064326	-.0333421	.0896137	.1493799	.2401705

Figure 7.5. A list of the first five DFBETA variables

Since the inclusion of an observation can either contribute to an increase or decrease in a regression coefficient, the DFBETA values could be either positive or negative. However, a DFBETA value in excess of 2/sqrt(n) is typically considered to merit further investigation. Thus, I was concerned about absolute values in excess of 2/sqrt(277) (or 0.1202) (see Figure 7.6). I next plotted onto a graph all eight DFBETA values by student Unique IDs. Many observations were found outside of the 0.1202 cut-off point, with students from the Independent School (in yellow) and SP4MLJ05 and CAT06A002 particularly notable.

Figure 7.6. Scatter plot of DFBETA values by Unique ID

Finally, in my search for unusual and influential data, I created an added-variable plot to graph each independent variable by student zBMI. The graphs in Figure 7.7 showed that the plotted regression lines were on the same slope (horizontal) as the coefficient for each independent variable.

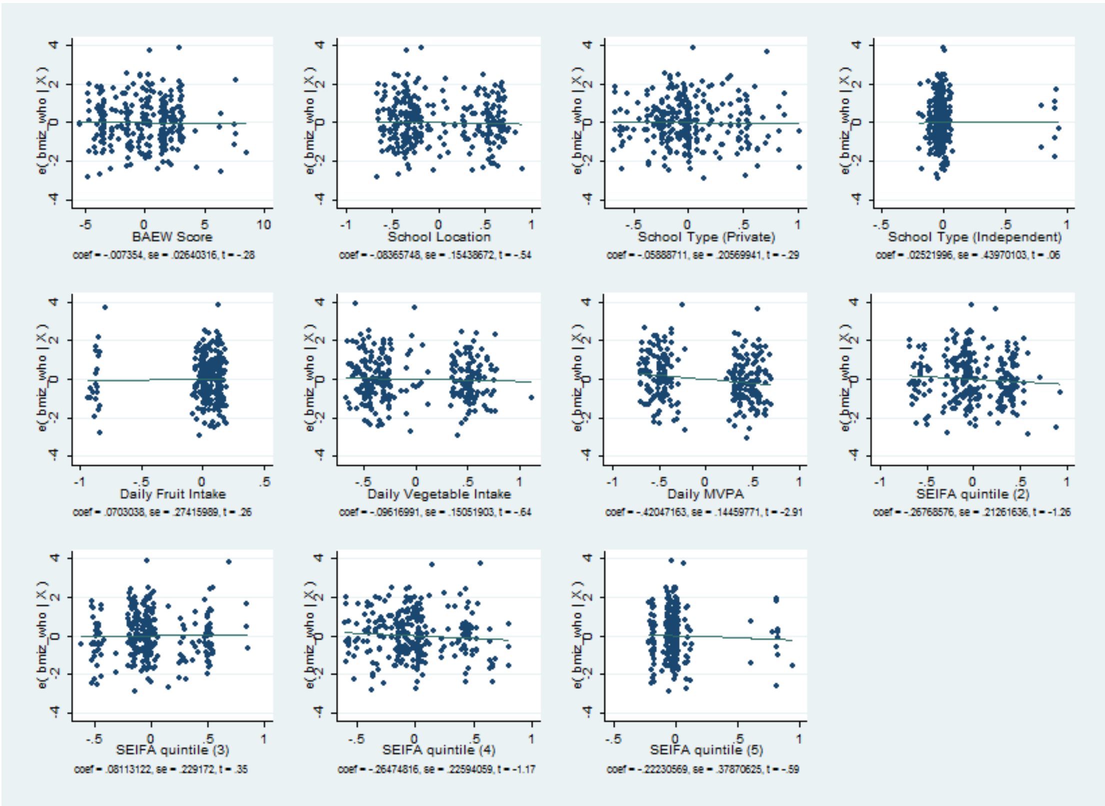


Figure 7.7. Added-value plot for each independent variable by student zBMI

In every analysis I completed, the group of Independent school students and SP4MLJ05 appeared as outliers or influential data points. During data collection, we only recruited one Independent school (with 8 male students) as part of the HTV evaluation and I used this to justify omitting it from future models. SP4MLJ05, however, despite recording the highest zBMI score in the entire sample, I deemed this insufficient reason to omit it from my analysis — I found no data entry error and I considered it important to capture the full range of weight outcomes amongst students.

I next re-ran the multivariate regression model with the Independent school removed (see Table 7.3). However, its omission had little impact on the coefficient for School Type, other coefficients, or the model fit.

Table 7.3. Adjusted multivariable regression model between student zBMI (n = 269 males) and BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.078	0.662	0.104
BAEW Score	-0.008	0.026	0.760
School Location	-0.088	0.154	0.567
School Type	-0.060	0.205	0.772
Daily Fruit Intake	0.059	0.274	0.829
Daily Vegetable Intake	-0.076	0.152	0.618
Daily MVPA	-0.390	0.146	**0.008**
SEIFA quintiles			
2	-0.277	0.214	0.195
3	0.092	0.300	0.690
4	-0.266	0.225	0.239
5	-0.176	0.400	0.661

Number of Obsv.	269 males
F-statistic	1.24
p-value	0.266
R-squared	0.046

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

In this section, I completed a number of tests to identify outliers and influential points. I used residuals, leverage, and Cook's D to assess the overall impact of observations on my regression results, as well as DFBETAs to assess the specific impact of an observation on the regression coefficients. Overall, I found that the Independent school was a point of major concern.

Normality of residuals

An important requirement of valid hypothesis testing in multivariate regression is to have normality of residuals. Normality required that the residuals (errors) be identically and independently distributed. Using STATA IC 13.0, I checked the normality of residuals. I produced a 'kernel density plot' with the normal option, adding a normal density overlaid onto the plot. Generally speaking, a k-density plot is thought of as a histogram with narrow bins and a moving average (see Figure 7.8). I also plotted the quantiles of a variable against the quantiles of a normal distribution (q-plot). A q-plot is sensitive to non-normality near the tails. As shown in Figure 7.9, the results from q-plot showed a slight deviation from normal at the upper tail due to SP4MLJ05 and WST04B001. Nevertheless, this was a minor overall deviation from normality and I accepted from these observational tests that the residuals were normally distributed.

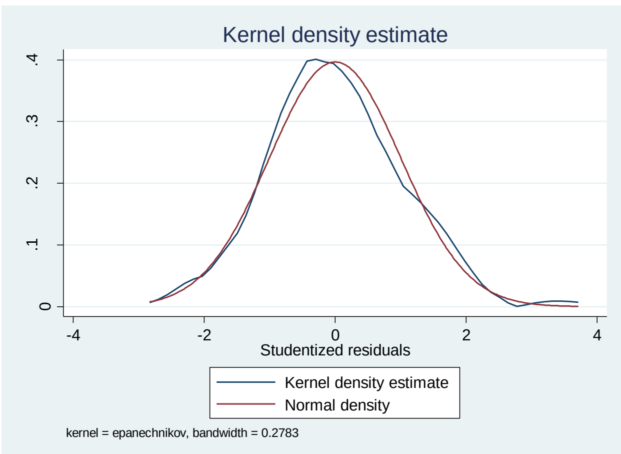


Figure 7.8. Kernel density plot to check normality of residuals

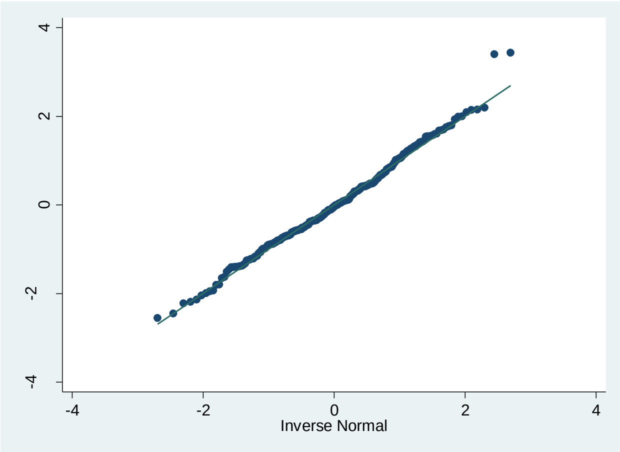


Figure 7.9. Q-plot to check normality of residuals

Homoscedasticity

Another key assumption of regression model building is the homogeneity of variance in the residuals. If a model is well-fitted, there should be no pattern to the residuals plotted against the fitted values. If the variance of the residuals is non-constant, then the residual variance is said to be "heteroscedastic".

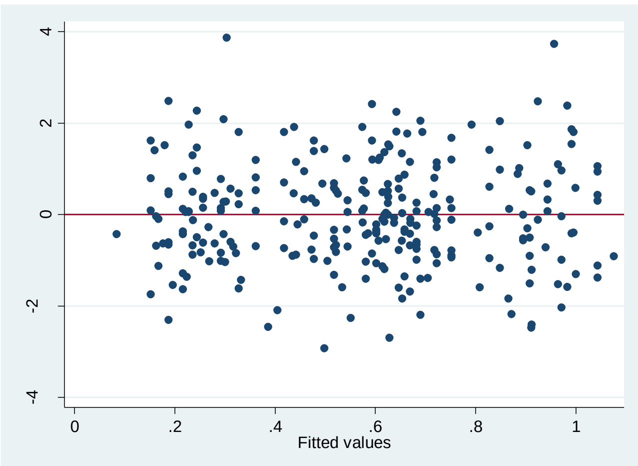


Figure 7.10. Plot of residuals versus fitted values

As shown in Figure 7.10, a commonly used graphical method for detecting heteroscedasticity is to plot the residuals versus fitted (predicted) values; I also added a **yline(0)** to put a reference line at residuals y=0. The plot showed that there was no obvious pattern of the data points, indicating that there was no heteroscedasticity.

<u>Multicollinearity</u>

The term multicollinearity implies that two variables are near perfect linear combinations of one another. When there is a perfect linear relationship amongst the independent variables, the estimates for a regression model cannot be uniquely computed. The primary concern in model building is that as the degree of multicollinearity increases, the regression model estimates of the coefficients become unstable and the standard errors for the coefficients become wildly inflated. So, I checked for multicollinearity (after regression). If a variable's variance inflation factor (VIF) values were greater than 10, they conventionally merited further investigation.

Table 7.4. Variance inflation factor (VIF) values (adjusted model)

Variable	VIF	1/VIF
BAEW Score	1.35	0.740
School Location	1.12	0.890
School Type (Independent school removed)	1.57	0.636
Daily Fruit Intake	1.07	0.938
Daily Vegetable Intake	1.11	0.902
Daily MVPA	1.06	0.947
SEIFA quintiles		
2	1.73	0.576
3	1.55	0.644
4	1.61	0.621
5	1.13	0.883

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

Tolerance, defined as 1/VIF, was commonly used by researchers to check on the degree of collinearity. A tolerance value lower than 0.1 was comparable to a VIF of 10, which essentially meant that a variable could be considered as a linear combination of other independent variables. As shown in Table 7.4, I found no concern for multicollinearity.

Linearity

I checked the assumption of linearity by plotting the standardized residuals against each of the independent variables. If there was a clear nonlinear pattern, there was a problem of nonlinearity. Otherwise, I should hope to have found for each of the plots a random scatter of data points. Figure 7.11 shows a matrix graph of all variables included in my multivariate regression model, where I found no clear nonlinear patterns.

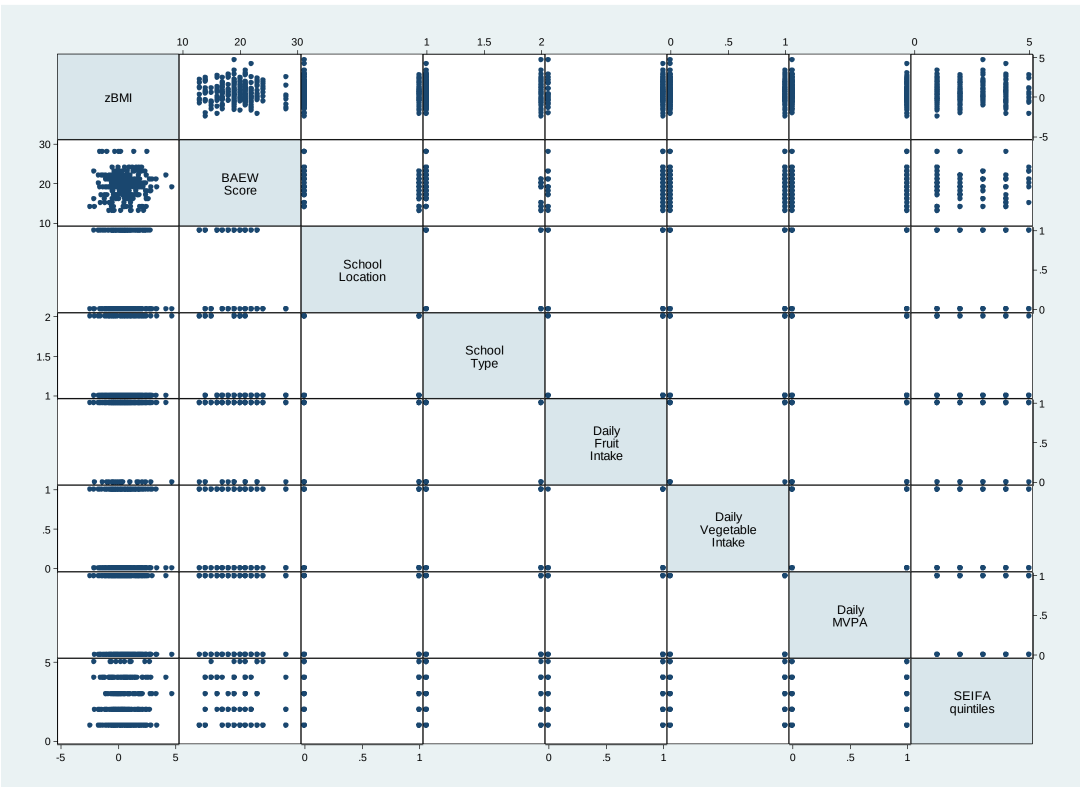


Figure 7.11. Matrix graph of dependent and independent variables

Model specification error

Lastly, I tested for model specification error, which occurs when one or more relevant variables were omitted from the model, or one or more irrelevant variables were included in the model. If relevant variables were omitted from the model, the common variance they shared with included variables may have been wrongly attributed to those variables, and the error term was inflated. On the other hand, if irrelevant variables were included in the model, the common variance they shared with included variables may have been wrongly attributed to them. Model specification errors can substantially affect the estimate of regression coefficients. I tested for model specification errors using STATA IC 13.0, which uses its built-in "linktest"— based on the notion that if a regression model was properly specified, I should not be able to identify any additional independent variables that were significant except by chance.

```
. linktest

      Source |       SS       df       MS              Number of obs =     315
-------------+------------------------------           F(  2,   312) =    1.80
       Model |  4.80465256     2  2.40232628           Prob > F      =  0.1678
    Residual |  417.548727   312   1.3382972           R-squared     =  0.0114
-------------+------------------------------           Adj R-squared =  0.0050
       Total |   422.35338   314  1.34507446           Root MSE      =  1.1568

------------------------------------------------------------------------------
    bmiz_who |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        _hat |  -1.175391   5.514003    -0.21   0.831    -12.02472    9.673941
      _hatsq |   1.871108   4.719957     0.40   0.692    -7.415863    11.15808
       _cons |   .6043273    1.55985     0.39   0.699    -2.464828    3.673483
------------------------------------------------------------------------------
```

Figure 7.12. Model specification error

The "linktest" created two new variables, the variable of prediction, '_hat', and the variable of squared prediction, '_hatsq'. The '_hatsq' variable should not be a significant predictor if the model was specified correctly, and from the above linktest, the test of '_hatsq' was not significant. That is to say that the linktest failed to reject the assumption that the model was specified correctly. Therefore, this result indicated that I did not have any specification error.

Clustering

In addition to my final adjusted model, I looked at clustering, which concerns the assumption of independence. It was possible that students within a school were more like one another than students from a different school; that is, their errors were not independent. Therefore, I tested if observations were clustered into schools and if observations were correlated within schools, but independent between schools. Prior to looking at clustering, Table 7.5 shows the multivariate regression model after all assumptions has been tested and met (except for independence) and the Independent school was removed.

Table 7.5. Adjusted multivariable regression model between student zBMI (n = 269 males) and BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.078	0.662	0.104
BAEW Score	-0.008	0.026	0.760
School Location	-0.088	0.154	0.567
School Type	-0.060	0.205	0.772
Daily Fruit Intake	0.059	0.274	0.829
Daily Vegetable Intake	-0.076	0.152	0.618
Daily MVPA	-0.390	0.146	**0.008**
SEIFA quintiles			
2	-0.277	0.214	0.195
3	0.092	0.230	0.690
4	-0.266	0.225	0.239
5	-0.176	0.400	0.661

Number of Obsv.	269 males
F-statistic	1.24
p-value	0.268
R-squared	0.046

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

Table 7.6 shows my final multivariate regression model, adjusted for clustering between schools. A total of 269 male students from 33 different primary schools were included. The coefficient estimates explored the relationship between my dependent variable and the independent variables, which in this case explained the amount of increase in student zBMI that would be predicted by a one-unit increase in the variables of interest.

Table 7.6. Adjusted multivariable regression model between student zBMI (n = 269 males) and BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.078	0.429	0.017
BAEW Score	-0.008	0.019	0.678
School Location	-0.088	0.140	0.534
School Type	-0.060	0.239	0.805
Daily Fruit Intake	0.059	0.234	0.802
Daily Vegetable Intake	-0.076	0.092	0.415
Daily MVPA	-0.390	0.104	**0.001**
SEIFA quintiles			
2	-0.277	0.246	0.269
3	0.092	0.285	0.750
4	-0.266	0.268	0.328
5	-0.176	0.508	0.732

Number of Obsv.	269 males
F-statistic	2.53
p-value	0.023
R-squared	0.046

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

Self-reported daily MVPA was significantly associated with student zBMI from beginning to end of the model building process. Adjusting for clustering between schools improved the model fit, but had little effect on the coefficients. However, the R-squared statistic was still low (0.046), indicating that five per cent of the variance in student zBMI was explained by the model. Referring to my primary research question, I found no significant association between student zBMI and the amount that schools did to promote healthy eating and PA amongst male students.

Female students

I next repeated the same model building process for female students and for my primary research question. In this analysis, the primary outcome variable was student zBMI and my independent variables were the BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, and SEIFA quintiles. My sample of female students was reduced from 380 to 278 because, similar to males, a number of students did not self-report their Daily Fruit Intake, Daily Vegetable Intake or Daily MVPA. Table 7.7 presents a regression model for female students only, adjusted for clustering and with the Independent school again removed because it was found to be influential.

Table 7.7. Adjusted multivariable regression model between student zBMI (n = 278 females) and BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.545	0.587	0.013
BAEW Score	-0.047	0.024	**0.056**
School Location	0.103	0.137	0.455
School Type	-0.369	0.253	0.154
Daily Fruit Intake	-0.188	0.227	0.413
Daily Vegetable Intake	0.237	0.146	0.113
Daily MVPA	-0.150	0.118	0.213
SEIFA quintiles			
2	-0.227	0.223	0.317
3	0.008	0.239	0.974
4	-0.268	0.200	0.263
5	-0.665	0.218	**0.005**

Number of Obsv.	278 females
F-statistic	4.29
p-value	0.001
R-squared	0.055

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

The model fit was improved by adjusting for clustering, but it had little effect on the coefficients. The R-squared statistic was again low (0.055) and it indicated that six per cent of the variance in student zBMI was explained by the included predictors. The BAEW Score was not significantly associated with student zBMI amongst female students (*p*-value = 0.056). However, this was the first instance where I observed a close-to-significant association (0.056) between student zBMI and the amount that schools were doing to promote healthy eating. Furthermore, the fifth SEIFA quintile was significantly associated with student zBMI (*p*-value = 0.005), which represented the area of greatest advantage amongst students.

Male and female students

I next repeated the same model building process for both male and female students and for my primary research question. In this analysis, the primary outcome variable was student zBMI and my independent variables were the BAEW Score, Gender (instead of splitting my models by sex), School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, and SEIFA quintiles. The sample size was reduced from 715 to 547 because a number of students did not self-report their Daily Fruit Intake, Daily Vegetable Intake or Daily MVPA. Table 7.8 presents a regression model that is adjusted for clustering and with the Independent school removed because it was again found to be influential.

Table 7.8. Adjusted multivariable regression model between student zBMI (n = 547) and BAEW Score, Gender, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.420	0.373	0.001
BAEW Score	-0.271	0.014	0.054
Gender	-0.298	0.106	**0.009**
School Location	-0.015	0.087	0.864
School Type	-0.200	0.146	0.181
Daily Fruit Intake	-0.061	0.199	0.759
Daily Vegetable Intake	-0.093	0.074	0.218
Daily MVPA	-0.275	0.088	**0.004**
SEIFA quintiles			
2	-0.225	0.166	0.185
3	0.077	0.175	0.664
4	-0.261	0.163	0.119
5	-0.415	0.229	0.080

Number of Obsv.	547
F-statistic	3.81
p-value	0.002
R-squared	0.045

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

The model fit was improved by adjusting for clustering, but it had little effect on the coefficients. The R-squared statistic was low (0.045) and it indicated that five per cent of the variance in student zBMI was explained by included predictors. The BAEW Score was not significantly associated with student zBMI (*p*-value = 0.054), but Gender (*p*-value = 0.009) and Daily MVPA were significantly associated with student zBMI (*p*-value = 0.004); Daily MVPA was previously shown in Table 7.6 to be significantly associated with student zBMI in males, but not in females.

7.3 Subsidiary research questions

My thesis included three subsidiary research questions (see Chapter 4.3). The first was answered by my systematic review publication, while the second expanded upon my primary research question and tested if there was a statistical association between student zBMI and either of the school Food or PA environment. I looked next at the school Food and PA Scores, before moving onto my final subsidiary research question, which tested for associations between student MVPA as measured by accelerometery and the school environment.

7.3.1 Student zBMI and the school food environment

My analysis of the BAEW Score was followed up with a closer look at student zBMI and the school environmental actions in place to promote healthy eating (Food Score). For both male and female students, I found that the Independent school was highly influential and I removed it from final adjusted models. All other assumptions of the model building process were met. I first looked at the sample of male students. As shown in Table 7.9, I found no significant association between student zBMI and the school Food Score amongst boys. The model fit was improved when adjusted for clustering, but it had little effect on the coefficients. The R-squared statistic remained low (0.048). Student self-report MVPA was again significantly associated with student zBMI (*p*-value = 0.001).

Table 7.9. Adjusted multivariable regression model between student zBMI (n = 269 males) and Food Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.335	0.394	0.002
Food Score	-0.028	0.020	0.162
School Location	-0.116	0.131	0.385
School Type	-0.069	0.255	0.788
Daily Fruit Intake	0.046	0.235	0.845
Daily Vegetable Intake	-0.077	0.091	0.405
Daily MVPA	-0.393	0.103	**0.001**
SEIFA quintiles			
2	-0.298	0.244	0.231
3	0.075	0.288	0.795
4	-0.292	0.270	0.289
5	-0.168	0.501	0.739

Number of Obsv.	269 males
F-statistic	2.84
p-value	0.013
R-squared	0.048

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

I next looked at my sample of female students. As shown in Table 7.10, **I found a statistically significant association between student zBMI and the school Food Score amongst girls.** The model fit was improved once adjusted for clustering, but it had little effect on the coefficients, and the R-squared statistic was still low (0.062).

Table 7.10. Adjusted multivariable regression model between student zBMI (n = 278 females) and Food Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	1.707	0.566	0.005
Food Score	-0.081	0.028	**0.007**
School Location	0.105	0.128	0.417
School Type	-0.306	0.214	0.163
Daily Fruit Intake	-0.209	0.228	0.366
Daily Vegetable Intake	0.224	0.147	0.136
Daily MVPA	-0.170	0.113	0.143
SEIFA quintiles			
2	-0.230	0.219	0.301
3	-0.031	0.241	0.898
4	-0.208	0.190	0.282
5	-0.644	0.218	**0.006**

Number of Obsv.	278 females
F-statistic	4.78
p-value	0.001
R-squared	0.062

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

I found a significant association amongst girls between student zBMI and the Food Score (*p*-value = 0.007), meaning that girls who attended a school doing more to promote healthy eating had a lower mean zBMI. It was unclear why this association between weight status and the school eating environment was significantly associated with females and not males. The fifth SEIFA quintile was also significantly associated with student zBMI (*p*-value = 0.006).

7.3.2 Student zBMI and the school PA environment

I next explored the association between student zBMI and the PA Score. Again, for both male and female students I found that the Independent school was highly influential and I removed it from all adjusted models. All other assumptions of the model building process were met. Table 7.11 shows that there was no significant association between student zBMI and the school PA Score amongst boys. The R-squared statistic remained low (0.046) and the model fit had been improved once adjusted for clustering. Student self-report MVPA was again significantly associated with student zBMI (*p*-value = 0.001).

Table 7.11. Adjusted multivariable regression model between student zBMI (n = 269 males) and PA Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable		Coefficient	Std. Error	*p*-value
Constant		0.831	0.407	0.049
PA Score		-0.010	0.036	0.784
School Location		-0.072	0.134	0.594
School Type		-0.015	0.239	0.950
Daily Fruit Intake		0.058	0.237	0.807
Daily Vegetable Intake		-0.079	0.094	0.404
Daily MVPA		-0.391	0.104	**0.001**
SEIFA quintiles				
	2	-0.269	0.254	0.298
	3	0.090	0.287	0.756
	4	-0.238	0.270	0.385
	5	-0.183	0.501	0.718
Number of Obsv.	269 males			
F-statistic	2.88			
p-value	0.012			
R-squared	0.046			

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; SEIFA = Socio-Economic Index for Areas.

Female students

I next looked at my sample of female students. As shown in Table 7.12, student zBMI was not significantly associated with the school PA Score amongst girls. The model fit was improved when adjusted for clustering and R-squared statistic was low (0.044). Despite the lack of association between student zBMI and the PA Score, the fifth SEIFA quintile was again significantly associated with student zBMI (*p*-value = 0.007).

Table 7.12. Adjusted multivariable regression model between student zBMI (n = 278 females) and PA Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	0.562	0.365	0.133
PA Score	-0.008	0.034	0.823
School Location	0.175	0.130	0.187
School Type	-0.223	0.253	0.385
Daily Fruit Intake	-0.158	0.246	0.525
Daily Vegetable Intake	0.238	0.148	0.118
Daily MVPA	-0.133	0.134	0.328
SEIFA quintiles			
2	-0.158	0.212	0.462
3	0.063	0.249	0.802
4	-0.132	0.210	0.535
5	-0.747	0.261	**0.007**

Number of Obsv.	278 females
F-statistic	2.78
p-value	0.014
R-squared	0.044

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity.

7.3.3 Including the Aust-HEI Score in model building

I next looked at answering my primary and secondary research questions using a dietary index score that I adapted from the Aust-HEI Score. At the individual-level, I did not find a significant association between student zBMI and Aust-HEI scores, with no difference observed between male and females. I then applied the using the Aust-HEI Score as part of the same model building process shown previously; I ran two different models that looked at the BAEW Score and the Food Score. I included Gender in these models instead of separating them by sex, as well as dropping my measures for daily fruits and vegetables intake.

In my first analysis, the primary outcome variable was student zBMI and my independent variables were the BAEW Score, Gender, School Location, School Type, Aust-HEI Score, Daily MVPA, and SEIFA quintiles. My sample size was reduced from 715 to 532 because a number of students did not self-report their Daily Fruit Intake, Daily Vegetable Intake or Daily MVPA (as components included in the Aust-HEI Score). Table 7.13 below presents a regression model after adjusting for clustering and with the Independent school again removed because it contained influential data.

Table 7.13. Adjusted multivariable regression model between student zBMI (*n* = 532) and BAEW Score, Gender, School Location, School Type, Aust-HEI Score, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Coefficient	Std. Error	*p*-value
Constant	0.967	0.436	0.034
BAEW Score	-0.024	0.014	0.098
Gender	-0.288	0.113	**0.016**
School Location	0.033	0.083	0.694
School Type	-0.174	0.152	0.261
Aust-HEI Score	0.010	0.005	0.061
Daily MVPA	-0.277	0.090	**0.004**
SEIFA quintiles			
2	-0.214	0.167	0.211
3	0.038	0.177	0.831
4	-0.245	0.173	0.168
5	-0.413	0.240	0.095

Number of Obsv.	532
F-statistic	4.01
p-value	0.001
R-squared	0.044

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; Aust-HEI = Australian Healthy Eating Index; SEIFA = Socio-Economic Index for Areas.

The model fit was improved by adjusting for clustering and the R-squared statistic (0.044) indicated that four per cent of the variance in student zBMI was explained by the included independent variables. The BAEW Score was not significantly associated with student zBMI amongst male and female students (*p*-value = 0.098). Similar to what I observed in previous models, Gender and Daily MVPA were significantly associated with student zBMI (*p*-value = 0.004 and *p*-value = 0.016, respectively). The Aust-HEI Score was not significantly associated with student zBMI in this model (*p*-value = 0.061).

Using the Aust-HEI Score once again, I next looked at student zBMI and the Food Score. I included Gender in the models instead of separating the model by sex, as well as dropping my indicators for daily fruit and vegetable intake. The primary outcome variable was student zBMI and my independent variables were the Food Score, Gender, School Location, School Type, Aust-HEI Score, Daily MVPA, and SEIFA quintiles. Table 7.14 presents a model after adjusting for clustering and with the Independent school removed because it was found to contain influential data. The model fit was improved by adjusting for clustering and the R-squared statistic (0.048) indicated that five per cent of the variance in student zBMI was explained by the included independent variables.

Table 7.14. Adjusted multivariable regression model between student zBMI (*n* = 532) and Food Score, Gender, School Location, School Type, Aust-HEI Score, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable		Coefficient	Std. Error	*p*-value
Constant		1.150	0.413	0.009
Food Score		-0.048	0.017	**0.008**
Gender		-0.294	0.113	**0.014**
School Location		0.017	0.076	0.824
School Type		-0.155	0.139	0.273
Aust-HEI Score		0.010	0.005	0.058
Daily MVPA		-0.287	0.089	**0.003**
SEIFA quintiles				
	2	-0.229	0.163	0.171
	3	0.007	0.181	0.967
	4	-0.252	0.159	0.122
	5	-0.398	0.225	0.088

Number of Obsv.	532
F-statistic	6.81
p-value	0.000
R-squared	0.048

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity; Aust-HEI = Australian Healthy Eating Index; SEIFA = Socio-Economic Index for Areas.

I found that the Food Score was significantly associated with student zBMI amongst male and female students (*p*-value = 0.098); a noteworthy difference to previous models was that this result was found with both males and females included in the same analysis. I also ran this model separated by males and females, but both models did not report a significant association between the Food Score and student zBMI — so the association was only found when both males and females were included in the model. The Aust-HEI Score was not significantly associated with student zBMI (*p*-value = 0.058), but it provided a much stronger association with student zBMI when compared to my measures for daily fruit and vegetable intake.

7.3.4 Student MVPA and the school environment

Finally, I looked at student MVPA, as measured by accelerometery, and its association with the school environment. A portion of students did not self-report their daily amount of MVPA and the final sample size was reduced to 208 students. Due to the reduced sample size, I opted to not separate my analysis by gender, despite males being significantly more active than females ($X^2 = 5.598$, p-value = 0.018) – 96.4% of males versus 88.2% of females met the recommended daily amount of MVPA. Because my primary outcome variable was binomial, the appropriate type of statistical test was logistic regression, which reported the Odds Ratio (OR) — a commonly used measure of association between an exposure and outcome.[170]

The variables included in the model were student MVPA accelerometery, the BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Veg Intake, Daily MVPA, and SEIFA quintiles. The Independent school proved again to be highly influential and I removed it from my model. The fifth (5) SEIFA quintile was also removed because it contained no data, reducing the final sample size to 191. All other assumptions of the model building process were met. Table 7.15 shows that the final adjusted regression model was not statistically significant, once adjusted for clustering. The same was found when I used the PA Score instead of the BAEW Score, or if I used MVPA accelerometery as a continuous variable (using multivariate regression).

Table 7.15. Adjusted OLS regression between student MVPA accelerometery (n = 191) and BAEW Score, School Location, School Type, Daily Fruit Intake, Daily Vegetable Intake, Daily MVPA, SEIFA quintiles (Independent school removed) (adjusted for clustering)

Variable	Odds Ratio	Std. Error	*p*-value
BAEW Score	0.894	0.097	0.303
School Location	1.164	0.666	0.790
School Type	0.510	0432	0.427
Daily Fruit Intake	1.548	1.334	0.612
Daily Vegetable Intake	1.427	0.885	0.566
Daily MVPA	2.127	1.305	0.219
SEIFA quintiles			
2	0.205	0.205	0.107
3	0.232	0.241	0.160
4	0.200	0.197	0.102

Number of Obsv.	191 male and female students
p-value	0.563
R-squared	0.067

zBMI = Body Mass Index z-scores; MVPA = Moderate-to-Vigorous Physical Activity

7.4 Summary of chapter

I separated my regression models by gender because of the significant difference in student zBMI between males and females. Students from the only Independent school proved a constant issue and they were dropped from all final adjusted models. Looking specifically at three of my research questions (the fourth was completed along with my systematic review), I found the following results:

1. I found no association between student zBMI and the BAEW Score. In males, student zBMI was significantly associated with self-reported Daily MVPA (*p*-value = 0.001). In females, student zBMI was significantly associated with the highest indicator for an area's advantage (*p*-value = 0.005).
2. Student zBMI was significantly associated with the school Food Score amongst females (*p*-value = 0.007); it was also significantly associated with both male and female students *if* I included the Aust-HEI Score in the model building process. In males, student zBMI was again significantly associated with self-reported Daily MVPA (*p*-value = 0.001). In females, student zBMI was again significantly associated with the highest indicator for an area's advantage (*p*-value = 0.006).
3. Student MVPA, as measured by accelerometery, had no associations with the school environment, but it was significantly associated with a number of student-level variables.

The next chapter presents a discussion of my results, highlighting their limitations and implications for future research, practice, and policy.

- 8 -

DISCUSSION: Findings and recommendations

8.1 Outline of chapter

In this chapter, I review my research questions from the perspectives of gender differences, Indigenous Australian disadvantage, and school-level variations found within the data set that were associated with student zBMI. I critique the strengths and limitations of my methodology and analysis, and conclude the chapter with a discussion of my main results and their implications for future research, policy, and practice.

8.2 Principal findings

My thesis aimed to answer the following primary research question:

RQ1. Is there an association between student zBMI and the number of school environmental actions in place to promote healthy eating and PA amongst students, as measured by the BAEW questionnaire?

and three subsidiary research questions:

RQ2. How do researchers characterise the school environment in determining its effect on student obesity? (systematic review)

RQ3. Is there an association between student zBMI and either of the school Food or PA environments?

RQ4. Is there an association between student MVPA, as measured by accelerometery, and the number of school environmental actions in place to promote PA amongst students, as measured by the BAEW questionnaire?

8.2.1 Was there an association between student zBMI and the number of school environmental actions in place to promote healthy eating and physical activity amongst students, as measured by the Be Active Eat Well questionnaire?

I describe in this section the associations between student- and school-level factors. I look closer at the sample I used to test for these associations — looking first at the student-level variables, followed by a critique of the included school-level data.

Student-level findings

My final sample included 715 students from Years 4 and 6 across 34 different primary schools. The response rate amongst students was 32.97% and no data were collected for survey non-respondents. The final sample was drawn from across 26 LGAs in the state of Victoria — an area almost twice the size of England. From the students included in my final sample, 31.3% (95%CI 30.9 to 31.7) were classified as O&O. This was above the Australian average (25.0%) and the Victorian average (28.6%), which had been reported in 2011 for children aged 2-12 years.[15,35] So, either my sample of students was not representative of the broader population in the included LGAs, or that childhood O&O was tracking more quickly in these LGAs compared to the Victorian average (there were 89 LGAs in Victoria). The latter is potentially more likely given that one-third of Victorian children aged 5-19 years had been previously predicted to be O&O by 2025; however, it was difficult to determine which explanation was more accurate without further research or surveillance.[36]

Regarding my primary research question, I found no association between student zBMI and the number of school environmental actions in place to promote healthy eating and PA, as measured by the BAEW questionnaire (see Section 7.2). I checked for a number of statistical assumptions that underpinned this type of analysis and controlled for a range of intermediary factors. I adjusted my analysis for clustering because of the likelihood that students within one school were more like one another than students in a different school. I also separated this analysis by gender due to the significant difference in student zBMI between males and females.

Amongst the sample of male students (n = 269), I found that those who were most active (met the recommended amount of daily MVPA) were significantly associated with a lower zBMI (coef. = -0.390; p-value = 0.008). The same outcome was not found in females. It has been reported in the peer-reviewed literature that children tended to over-report their PA behaviours,[148] but I could not test for this without further research. Nonetheless, it was not possible to determine causality in any direction due to the cross-sectional study design of the HTV evaluation.

Amongst the sample of female students (n = 278), those living in the areas of greatest advantage, as measured by the SEIFA score (in the 5^{th} quintile), were significantly associated with a lower zBMI (coef. = -0.665, *p*-value = 0.005). This indicator of socio-economic status was determined using the student's home postcode, which was provided by the student as part of the self-report behavioural questionnaires. The ABS broadly defined socio-economic advantage and disadvantage as "people's access to material and social resources, and their ability to participate in society".[162] It was perhaps unsurprising that female students who lived in some of the most affluent parts of Victoria (n = 19) had a lower risk of being O&O, given that people from high-income households often experienced a higher standard of living.[171] However, it was again not possible to determine causality in either direction.

Gender

Studies related to childhood O&O have increasingly looked to divorce their findings from the differences found between males and females. The variation between males and females is either the result of differences in biology (sex) or in gender (societal and cultural influences) — or both.[172] Sex and gender are both significant, but I discuss here only briefly the impact of sex on obesity, as my research was focused more on the behavioural factors rather than biological.

Researchers have struggled to determine the extent to which genetics contributes to obesity.[173] We know that males are represented by relatively greater fat in the upper body and females by relatively greater amounts in the hip and thigh area.[172] Until recently, sex differences in fat levels were thought to become manifest during puberty.[174] However, researchers have now discovered differences in pre-pubertal males and females as young as three years of age.[172] Studies have also found that the health risks become evident at lower levels of obesity in boys than for girls;[172] it is thus worth noting that the male participants in my analysis reported a 5.6% higher prevalence of O&O than girls.

So like height, weight is heritable. Genetic factors are involved in the regulation of body weight and biology plays an important part in explaining why fat levels differ between males and females.[175] I would argue, however, that gender-related factors are equally as important to understand because they are more amenable to change and intervention. The behavioural determinants of obesity include excess energy intake and inadequate energy expenditure. As discussed in my background chapters, obesity is the result of an imbalance between these two determinants (i.e. the amount of energy consumed versus the amount of energy spent).[10] A review by Goran (2001) suggested that an imbalance of just two per cent in children – the equivalent of around 30 calories – can lead to obesity.[176] Today, children are experiencing unprecedented access to energy-dense foods and sugary-sweetened beverages and increased portion-sizes, together with a significant decline over recent decades in daily PA levels and increased car travel and screen-based entertainment. These lifestyle changes are heavily implicated in the rise of childhood O&O.[65]

In males, I found a significant difference between male and female students between their student zBMI and self-reported daily MVPA (*p*-value = 0.000). Causality could not be determined, but energy expenditure has been strongly associated with gender differences in the peer-reviewed literature. For example, a longitudinal study by Legato (1997) found that total energy expenditure (TEE) for boys increased continuously between ages five and ten. TEE in girls increased from around 1,400 calories at age five to 1,600 calories at age six, but by age nine, their TEE had regressed to 1,400 calories.[176] Legato proposed that it was in large part the result of a 50% reduction in PA in girls between ages six and nine.[174]

Weight-related stigmatisation and discrimination by peers has long been recognised — in males and females. Obese children are at an increased risk of being characterised in a negative way, less preferred as friends, and more likely to be bullied or teased.[177] Evidence shows that school teachers can also present bias and stereotyping towards obese children.[178] Although gender is rarely the principal focus of the literature looking at these subjects, it is a common thread running through much of it. Biological differences between the bodies of boys and girls impact on abilities to engage in certain physical activities and dietary choices, but the culture-bound conventions and gender stereotypes are arguably just as, if not more, significant to a child's long-term health and wellbeing.

Indigenous Australians

The term Indigenous Australian represents more than 250 different language groups spread across the entire continent. In 2011, Indigenous Australians represented 3.0% (669,900) of the total Australian population.[67] It is a complex culture with traditions varying greatly depending on which language group they belong to or self-identify. Today, approximately 75% of Indigenous Australians reside in urban and regional parts of the country. Indigenous Australians have long suffered from social disadvantage and it represents a culture torn between its traditions and the Western lifestyle.[67] Indigenous Australians experience significantly higher rates of unemployment, poor educational attainment, and poor overall health and wellbeing.[67]

A critical period in which inequalities emerge is childhood.[179] In 2011, 30% of Indigenous Australian children aged 2-12 years were found to be O&O, compared to 25% in the general population (no data were available specific to Indigenous Australian children aged 8-12 years).[67] This gap between Indigenous and non-Indigenous children has also been widening.[179] From 1997 to 2010, rates of O&O rose by 22.4% in Indigenous Australian children compared with 11.8% for non-Indigenous children.[180] Findings from my analysis suggested that this gap has potentially grown wider in the LGAs included in the HTV evaluation.

Of the students included in my sample, 3.3% self-reported as Indigenous Australian. This response rate was a higher than expected given that Victoria comprised the lowest proportion (0.9%) of Indigenous Australians amongst all Australian states and territories.[71] However, the Indigenous Australian population is a much younger demographic compared to the general population and this could go some way to explaining why there were so many Indigenous Australian students in the sample. Alternatively, it is possible that national surveys have under-reported the size of the Indigenous Australian population; indeed, 49 of the students included my sample opted not to report their indigeneity — it was not possible to determine why they chose to opt-out without further research.

Indigenous Australian children are at increased risk of excess weight and this was shown to be accurate in my analysis. Mean zBMI amongst Indigenous Australian students was 1.30 compared to 0.45 in non-Indigenous students. However, my sample size for Indigenous Australian students (23) was far too small to be considered representative of the wider Indigenous Australian population. It is important nonetheless that the education community is aware of the increased risk for poor health outcomes amongst Indigenous Australian children, and that it endeavours to work with local Indigenous leaders when planning to improve eating and PA behaviours in schools.

School-level findings

The BAEW questionnaire had previously been applied to large, community-based intervention studies in schools around Victoria, but it had never been stripped back to its core list of questions (or at least not published).[132,133] Using the BAEW Score, I was able to find that schools had in place between 13 and 28 different environmental actions that promoted healthy eating and PA amongst students. Looking at how the BAEW questionnaire was developed and been previously used in studies, it is difficult to understand why this had not been done before.

The 'BAEW programme' – for which the BAEW questionnaire was originally developed – was a large, multi-faceted, community-based project that promoted healthy eating and PA amongst Victorian children aged 4-12 years. The BAEW programme collected school-level data from 18 intervention and control primary schools at baseline and follow-up, and the effect of the intervention was tested whilst controlling for child age, gender, and maternal education level. The BAEW programme has since been described as a success in the peer-reviewed literature; for example, Miller *et al.* (2011) reported significant reductions in weight gain amongst Australian primary school children — an Australian first.[35] The programme reported significant improvements at all levels of the intervention, including at the school-level.

In 2012, Johnson *et al.* published a multi-level analysis using the BAEW questionnaire.[181] The aims of this analysis were 1) To examine the relationship between changes in obesity-related individual-, household-, and school-factors, and changes in child zBMI, and 2) To determine if the BAEW programme moderated these effects. After accounting for the nested structure of the data set, Johnson *et al.* reported that the results presented by Miller *et al.* were valid — that the BAEW programme had indeed lowered student zBMI in comparison to the students from the control groups.[180] Importantly, Johnson *et al.* used data from the BAEW questionnaire to assess the school-level effect on student zBMI. However, the only school-level variables used by the authors were related to the presence or absence of a written school policy for healthy eating and PA — they reported a significant association between student zBMI and these two written policy variables (*p*-value = 0.008 and *p*-value = 0.006, respectively). The authors made note that these variables were "relatively blunt" and provided a narrow indication of the school healthy eating and PA context. However, given that I found 33 unique school-level variables using the BAEW questionnaire (see Section 4.4.5), it was unclear why Johnson *et al.* did not mention the other school-level data available to them, raising questions of a potential reporting bias against non-significant results.

At the student-level, Johnson *et al.* reported a significant association between student zBMI and sugary-sweetened beverage consumption (*p*-value = 0.030). In my analysis, I also found a number of associations between student-level variables. For example, student self-reported daily MVPA was significantly associated with Gender, Year Level, and Daily Vegetable Intake. Johnson *et al.* stated that the school-level data accounted for just 1% of the variance in their multi-level analysis; while the variation between household environments contributed to 59% of unexplained change in child zBMI, between baseline and follow-up, with the individual-level factors the second largest contributor at 23%.[180] Although I used multivariate regression – meaning I could not separate compositional and contextual factors such as when using multi-level modelling (MLM) – my R-squared statistic typically indicated that between four and six per cent of the variance in student zBMI was explained by my models, which was higher than reported by Johnson *et al.*[180] This could have been because the BAEW Score captured more information about what primary schools were doing to promote healthy eating and PA amongst students in comparison to Johnson *et al.*'s analysis.

A total of 27 Government and six Private schools were included in my final sample. From six months of visiting schools, and meeting thousands of students and school staff, I grew quite sensitive to the differences between schools. Students regularly stopped me during the survey period to ask why I was walking around the school grounds with a clipboard, speaking to their teachers, interviewing the "tuckshop lady" and school principal. Anecdotally, I asked dozens of teachers during their visits if they believed the school was a contributing factor to childhood obesity. I received responses ranging from zero impact to 100% responsible, and everything in between, and if one thing was clear from speaking to teachers, it was that there was little consensus amongst teachers about the importance of schools in preventing childhood obesity.

Much of my analysis was focused on the differences between schools, but the BAEW Score also revealed a number of similarities between schools. For example, only two schools considered their teaching staff to be healthy PA role models, while 30 out of 34 schools had a vegetable garden. Most schools considered their play areas (76%) and sporting equipment (91%) to be sufficient, and the vast majority of schools answered that making a profit was an important part of their food service (94%). I recall a school principal telling me during the survey:

"Without the school canteen turning a profit each year, we'd not have enough money in the budget to keep the school bus!"

In Australia, there is a wide gap between the quality of education received at Government and Private schools. Anecdotally, I could generally tell by just walking into a school if it was government- or privately-run; the facilities at Private schools were generally more modern and better-maintained. Private schools generally have fewer students per classroom and more teachers overall, with teachers in specialist areas such as sports and the arts. Private schools also had far larger budgets than Government schools and this is believed to result in improved teaching quality and facilities.[182] In Victoria, the total average cost of sending a child to a Private school was approximately eight times higher than for a Government education.[183] However, both School Types were regulated by the same curriculum standards framework, and, despite the aforementioned differences across the general population, it made little difference in terms of their BAEW Score results in schools included in the HTV evaluation.[183] I also found no difference in student zBMI between School Types (*p*-value = 0.391).

The prevalence of O&O amongst children and adults in the general population of Australia is higher in rural parts than in urban areas — so I controlled for School Location in my analysis.[184] Rural areas in Australia generally exhibited unique characteristics compared to urban areas, which would go some way to explaining the general disparities in O&O prevalence. Rural areas typically had a lower population density, fewer transport options, geographical isolation, and poorer access to healthcare, which has been hypothesised to influence a population's PA and dietary choices.[185] In my analysis, I found that student zBMI was slightly lower in urban areas in comparison to rural areas (0.47 and 0.50, respectively), but this difference was not statistically significant (*p*-value = 0.699). A study by Crawford *et al.* (2010) also reported no significant difference in zBMI amongst children aged 5-12 years between rural and urban parts of Victoria.[184] It could be that the 'rural effect', or association, with obesity takes hold later in life, or that the nation-wide effect is not felt as strongly in Victoria because of its relatively small size and closer proximity between cities.

8.2.2 How have researchers characterised the school environment in determining its effect on student obesity?

I conducted a systematic review of the evidence to better understand how researchers have been investigating the school's impact on student obesity. The review used broad terms to capture a total of 21,778 peer-reviewed articles, which was later reduced to just five articles that met the selection criteria. I found 65 other articles that had the required school- and student-level data to test for the school's impact on student obesity, but the authors potentially chose not to do so or not to report it. I concluded from my review that the research instruments being used to test for a school-to-student relationship were of limited and unknown quality, given the paucity of validity and reliability testing. I recommended that future research aimed to:

1) Include objective measurements whenever possible;
2) Collect data at both the school- and student-level;
3) Collect data relevant to both the food and PA environment;
4) Use statistical techniques that aimed to separate contextual and compositional factors; and,
5) Incorporate follow-up data.

8.2.3 Was there an association between student zBMI and either of the school Food or Physical Activity environments?

Poor diet and physical inactivity are the two leading causes of obesity, which is why I separated the BAEW Score into the 'Food Score' (23 questions related to the school eating environment) and the 'PA Score' (eleven questions related to the school PA environment).[9] I also separated my analysis by gender, as student zBMI was significantly higher amongst male students (p-value = 0.008). In males, student zBMI was not significantly associated with either of the school PA Score (p-value = 0.784) or Food Score (p-value = 0.162). The models were also improved when adjusted for clustering, but it had little effect on my coefficients. In females, however, I found that student zBMI was significantly associated with the school Food Score — female zBMI was lower in schools that did more to promote healthy eating (p-value = 0.007). No such association was found between student zBMI and the PA Score (p-value = 0.823).

The Food Score examined 23 questions related to the promotion of healthy eating amongst students. Food promotion is known to have a direct effect on a child's nutrition knowledge, preferences, purchase behaviour, consumption patterns, and diet-related health.[60] It was unclear why this association between student zBMI and the Food Score was not found in males, but this was at least consistent with other findings in my analysis that showed significant differences between male and female students.

In 2012, Osei-Assibey *et al.* published a review on the influence of the food environment on O&O in young children aged up to 8 years.[186] Thirty-five studies were included in the review, including 25 intervention studies and ten longitudinal studies. Although most of the children included in the review were aged 3-8 years – younger than the students included in my analysis (9-13 years) – but the authors reported moderately strong evidence to support a positive association between lower O&O with interventions related to food promotion, smaller portion-sizes, and fewer sugary-sweetened beverages.[185]

The school environment has been hypothesised to influence student health by means of compositional (which people are found in a place) and contextual factors (the characteristics of a place),[98] but it has proven very difficult to capture its impact on student weight outcomes. This was shown in my critique of the Cochrane review on childhood obesity prevention strategies, with study comparison fraught with difficulty (see Section 2.5).[39] Since the WHO pushed its Member States in the 1990s to adopt the HPS strategy – a more holistic approach to health promotion in schools – the evidence-base has remained weak in demonstrating a positive association between the type of school environment and the weight status of students — which makes the results in my analysis even more significant.[90]

In terms of maintaining a healthy body weight, it is difficult to unpack the significance of calorie intake versus calorie expenditure. The issue becomes even more complex when their importance differs between males and females. In 2010, Gutin published an article that discussed the importance of a healthy diet versus regular exercise in the prevention of childhood O&O.[187] He presented evidence that showed how childhood O&O prevention efforts tended to over-emphasise the reduction in energy-intake, and that increased PA was often allocated a supportive role. Gutin argued that preventive interventions should equally emphasise PA behaviours, rather than simply a greater restriction of energy-intake, to help youths lose weight and to increase lean muscle.[186] In the 2011-12 AHS, gender was not a significant factor for O&O in children aged 5-14 years — nor for self-reported dietary behaviours.[64] The female students in my analysis, however, had lower mean zBMI compared to males (0.38 and 0.60, respectively), which could in part explain why the Food Score was associated with females and not males. However, it is not possible to determine without further research in this area.

8.2.4 *Was there an association between student MVPA, as measured by accelerometery, and the number of school environmental actions in place to promote physical activity amongst students, as measured by the Be Active Eat Well questionnaire?*

In my analysis of student daily MVPA, as measured by accelerometery, and the school PA Score, my sample size was substantially reduced because of the limited number of available accelerometers (n = 257). The sample size was then reduced to 191 students, as a number of students did not self-report their dietary or PA behaviours. Given the small sample size, I did not separate my analysis by gender, despite males being more active than females (X^2 = 5.598, p-value = 0.018). I also chose not to separate my analysis by Year Level in order to increase my statistical power, even though students in Year 4 were more active than those in Year 6 (X^2 = 10.784, p-value = 0.001), which was consistent with other studies that have shown younger children to be more active.[64] All of the models with the accelerometery data set were a poor fit. I found no significant associations between MVPA accelerometery and the school environment — using either the PA Score or the BAEW Score. The same result was found if I used the MVPA accelerometery as a continuous variable. These findings could be the result of my sample size being too small, or potentially that it did not matter what the schools were doing to promote PA behaviours amongst students.

In collaboration with the other members of the HTV evaluation project leadership team, I was second-author on a publication that focused on individual-level factors and used the same accelerometery data set.[188] We assessed the composition of objectively-measured PA and sedentary behaviour participation amongst students across the school-day. A full account of this analysis was published in BMJ Open (see Appendix Four).[187]

8.3 Review of methods

In line with my research questions, my research objectives were:

1. To complete a systematic review of the evidence with respect to how researchers have characterised the school environment in determining its effect on student obesity;
2. To collect valid and reliable data on student zBMI and weight-related factors;
3. To collect valid and reliable school-level data on the promotion of healthy eating and PA in schools; and,
4. To investigate associations between student- and school-level factors.

I discuss in the following sections the strengths and weaknesses of the methods I used in fulfilling these research objectives.

8.3.1 Strengths and limitations of my systematic review

I completed a systematic review of the evidence to better understand how researchers were characterising the school environment in determining its effect on student obesity. A systematic review is widely regarded as the most reliable form of critique for peer-reviewed evidence. I followed the PRISMA review process and I registered the review on the PROSPERO register before any analysis took place. I did not go through any ethics clearance processes because it did not involve primary data collection.

My intention was to capture as many research articles as possible, using a broad range of terms and keywords. Exclusion criteria were developed and applied by two different researchers, achieving 100% agreement on final articles. A third reviewer was available to help resolve any disagreement concerning the exclusion criteria. We used a narrative synthesis of the evidence to collate and summarise the results of the studies. We limited our search to English-written studies, which reduced the review's generalisability. The review was not restricted by study design and we used the NOS tool to assess the quality of each included article.

I chose to apply the ANGELO framework to categorise the evidence because it helped to classify the school-level evidence into one of four environmental pillars: the economic (what were the costs), physical (what was available), political (what were the rules) and socio-cultural (what were the attitudes and beliefs) elements. This approach had not been done previously (as far I knew at the time). The ANGELO framework provided a useful mechanism for structuring and critiquing the school-level evidence, but it was also an effective communication tool. A limitation to this approach was the degree of subjectivity included when selecting which element of the ANGELO framework best suited the piece of school-level evidence; however, we aimed to limit this subjectivity and outlined the rationale behind each decision. I've described this methodology in more detail in Chapter Three, as well as in the peer-reviewed literature.[108]

8.3.2 Strengths and limitations on the collection of student-level weight-related factors

In order to collect such a large sample size, we employed 20+ research assistants to help collect the student-level data. I was co-responsible for screening applications, interviewing short-listed applicants, and organising two-days of training. In preparation for the training days, I co-wrote manuals for the Research Assistants to follow. These manuals included Participant Information and Consent Forms, equipment checklists, guidelines for collecting anthropometry and questionnaire data, and fire and safety guidelines. I invested a great deal of time into training the Research Assistants, because I knew that this preparation would help to reduce mistakes during data collection and improve the quality of my data set. During the survey period, we followed strict protocols and it was my responsibility to check that all equipment was set up and used properly throughout the survey.

A strength of my analysis was the quality of my primary outcome variable: student zBMI. BMI is a commonly-used measure of weight status and it was the recommended to be used by the Australian Government NHMRC.[62] All data were dual-entered following the data collection period by members of the HTV Evaluation Steering Committee. These data were then log-transformed using the WHO's international growth reference standards, which applied age-sex-specific BMI z-scores to define overweight (+1.0 to 2.0 SD) and obesity (+2.0 SD) (see Section 4.4.1).[136] I chose the WHO growth reference standards to allow for greater representativeness of my results and because I was working in collaboration with the WHOCC-OP.

The student behavioural data included in my analysis were not as robust as my primary outcome measure. There are a number of limitations to self-report health data, particularly amongst children. In the past, Australian national surveys have relied heavily on self-reported or parental-reported height (cm), weight (kg), and weight-related behavioural data to assess childhood obesity.[11] However, a reliance on children recalling dietary and PA outcomes can be problematic — a child may report behaviours that they perceive to be desirable, rather than accurate, which leads to response bias.[189] Due to these limitations, childhood obesity can be difficult to track and more authority should be given to studies that include more objective measures of dietary and PA behaviours.

We used the CDQ to collect student self-report dietary behaviour data. The CDQ was previously validated amongst Australian school children aged 4-16 years (see Section 4.4.2).[128] Development of the CDQ was based on the Australian dietary guidelines (2003). A panel of four paediatric dietary experts reviewed all items included in the questionnaire — reportedly to optimise content validity.[128] The readability of the pilot was assessed by testing with four parents. A limitation that should be considered to any future interpretation of the student dietary data we collected is that the CDQ was administered by either myself or another member of the project leadership team to the entire class of Year 4 or Year 6 students, which is not how the instrument was intended to be used; although the CDQ was designed to be used at the group level. The CDQ's internal consistency, test-retest reliability, and relative validity were tested among samples of parent-respondents for school-aged children — meaning that this instrument was designed for parents to complete the FFQ about their own children.[128] Thus caution should be taken when interpreting these results.

We used the SHAPES questionnaire to ask students to recall their PA behaviours over the previous seven days (see Section 4.4.3). A drawback of the questionnaire was its length, which included 45 unique items. The SHAPES questionnaire had been reported in the peer-reviewed literature as having acceptable reliability and validity.[129] It had moderate validity correlations for self-reported and accelerometery average MVPA minutes per day (Spearman's r = 0.44, p-value = 0.01).[129] The instrument's test-retest reliability was assessed by administering it twice; one week apart on a sample of 2,812 students in Years 9-12. The kappa coefficient for the 7-day test-retest reliability of the SHAPES questionnaire indicated moderate agreement (mean 0.57 ± 0.24). However, this was tested amongst a sample of Canadian youth aged eleven to 18 years and no reliability and validity testing had been done for Australian children and adolescents.[148]

The Australian national PA guidelines (2014) recommended that children aged 5-12 years do at least 60 minutes of MVPA per day.[84] Objective measures of PA behaviour, such as with accelerometery, are the preferred method to collect valid and reliable measures of student PA behaviour, as they provide a continuous measure of the frequency and amplitude of human movement to generate a "count", with larger counts considered indicative of higher intensities of PA.

However, we had difficulty in sourcing enough accelerometers so that one could be used by every student participating in the HTV evaluation. In the end, enough accelerometers were sourced so that we could give one to approximately every second student. We used ActiGraph GT3X and GT3X+ accelerometers to collect objective measures of PA behaviour. Only participants with data that had ≥3 days of monitoring were included. We overcame the intergenerational issue of the different ActiGraph accelerometer models by selecting a 15-second epoch and 30-hertz sampling rate, which had previously been shown to have strong agreement with total vertical axis counts, total VM counts, and MVPA levels amongst children and adolescents.[153] Different accelerometery studies have used different count cut-points and this can have important implications for research. For the purposes of the HTV evaluation, the steering committee applied count cut-points developed by Romanzini *et al.* (2014), which were developed specifically for the ActiGraph GT3X accelerometer model (see Section 4.4.4).[157]

The vast majority of students (91%) who wore an accelerometer for three or more valid days met the recommended daily amount of MVPA, which was always going to make it difficult to find any significant results with such a small sample size. We did not collect any data for non-respondents, but I was still able to compare the results between those students who wore an accelerometer and those who did not (see Section 6.5). The lowest mean zBMI (0.43) was observed amongst students who wore an accelerometer for three or more valid days. This was perhaps unsurprising given our method of recruitment. All students were required to opt-in to the survey (i.e. return a signed parental consent) in order to take part in the survey (RR = 32.97%), while a portion of students were then invited to wear an accelerometer for seven consecutive days (257 met the inclusion criteria [RR = 79.08%]). Therefore, there was a potential selection bias between the group of students who 1) gained permission from their parent/ guardian in order to participate in the survey and those who did not, and 2) between the students who successfully wore an accelerometer for three or more valid days and those who did not.

8.3.3 Strengths and limitations of school-level data on the promotion of healthy eating and physical activity

The BAEW questionnaire provided an assessment of school-level actions to promote healthy eating and PA amongst students. Its strengths were its ease-of-use, quickness to complete, and the breadth of school-level factors that it touched on. There was no burden on the student population and it had previously been applied to a large community-based intervention in schools across Victoria. It had been reported in the peer-reviewed literature as having high logic and face validity, but the measurement instrument had many limitations. The BAEW questionnaire went against many of the recommendations proposed in my systematic review. If I had had enough time between my joining the HTV evaluation project leadership team and the beginning of the survey, I would have included a repeatability study or some form of validity and reliability testing for the BAEW questionnaire.

The BAEW questionnaire has not undertaken any comprehensive validity and reliability testing. Until that time, any findings derived from using the BAEW questionnaire must be taken with caution, including those from my analysis. The BAEW questionnaire collected no objective data of the school environment. It relied entirely on the consensus of school staff members that were chosen to participate by the school principal. There was potential for this recruitment methodology to result in selection bias. The BAEW questionnaire incorporated no follow-up data and it was restricted to a cross-sectional study design — a 'snapshot' of what the schools were doing to promote healthy eating and PA amongst students.

During the data collection period, the BAEW questionnaire was usually completed during same school visit for when we collected student-level data. It involved a 20-30 minute interview with the school principal, a member of teaching staff (usually from physical education), and a member of the school catering staff. It was constructed with Swinburn *et al.*'s (1999) proposed four key pillars of the obesogenic environment in mind: the economics, physical, political, and socio-cultural elements.[43] It is unclear why Swinburn *et al.* considered the ANGELO framework as appropriate for the school setting. It was possible that the questions included in the BAEW questionnaire did not ask the most appropriate questions — answers relied on the consensus of interviewees nominated by the school. For example, it was possible that a teacher might stop from responding negatively about the school since the school principal was also in the room.

Finally, the BAEW questionnaire had little consistency in response types. For example, one question would use a Likert scale to rank responses, but the next question would use a different scale. Anecdotally, I noticed at times that this caused confusion amongst interviewees, which increased the chance of measurement bias.

8.3.4 Strengths and limitations of the investigation of associations between student- and school-level factors

The SEM to health infers that health emerges from day-to-day interactions between people and environments. The foundation of the SEM to health is that human behaviour cannot be understood without taking into consideration the context in which it occurs. The social determinants of health are at its foundation and it integrates multiple levels of influence to impact on health behaviour, while emphasising the interaction between factors within and across all levels of the health behaviour.[85] The SEM to health is there to help us to better understand and to illustrate the complex interplay between the many exposures that children face — it offers the greatest potential for answering large and complicated questions about how to prevent childhood O&O and unpick which contextual factors are having the greatest influence.

Schools provide unparalleled access to children and governments have targeted this well-defined setting for obesity prevention strategies. However, most children do not enter the schooling system until five years of age and these first five years of life, as well as in prenatal care, are significant in terms of child development.[38] This period is the foundation that shapes a child's future health, happiness, growth, development, and learning at school and in life in general.[190] Recent research has concluded that the first three years of life are the most critical in shaping a child's brain architecture; early experiences provide the base for the brain's organisational development and functioning throughout life.[191] They have a direct impact on how children develop learning skills as well as social and emotional skills.[192]

The SEM to health teaches us that many of today's public health challenges are too complex to be adequately understood with single-level analyses.[24] I had originally planned to approach the model building process using a multi-level model (MLM) to separate the compositional and contextual factors. I completed an MLM training course at Manchester University. A rule-of-thumb in MLM is to use a sample size of 30 x 30 (e.g. 30 students x 30 schools) to create a well-fitted model.[62] I had hoped that my data set would be suitable – my data set averaged 22 students across 33 schools – however, the intra-class correlation was zero and it was clear from early on in the model building process that my data were a poor fit for this type of analysis. This was possibly due to having too much variation in the sample size of students between schools. To illustrate, one school in the model would have fifty students, while the next had five. As a result, I approached my data set using a multivariate regression model.

Multivariate regression modelling was the next most appropriate statistical test to answer my research questions, having a continuous dependent variable and two or more independent variables. I checked for a number of assumptions that underpinned this type of analysis during the model building process. My coefficient estimates explored the relationship between the dependent variable (e.g. student zBMI) and independent variables (e.g. BAEW Score, School Location), which explained the amount of increase in the dependent variable predicted by a one-unit increase in the independent variable of interest. However, running so many regression models on the same data set increased my likelihood of residual confounding and multiple-testing bias.[193] My analysis was also restricted by the data type limitations that I outlined earlier in the chapter.

My analysis was not impacted by the HTV intervention, as the data set was collected at baseline. It captured a population of students at a single point in time and I was thus unable to determine any cause and effect. However, a cross-sectional study design is still able to measure the prevalence of O&O and multiple exposures — but not incidence. The 34 participating schools were randomly selected from with 26 different LGAs and spread across Victoria. With a response rate of 32.97% from invited students, selection bias was a limitation and substantially reduced the representativeness of my sample. We used an opt-in study design and every student had an equal chance to participate in the survey. However, students needed to return an Informed Consent Form signed by their parent/ guardian in order to participate, so it was possible that if a student (or their parent/ guardian) was concerned about their weight that they were less likely to participate in the survey than a student of a healthy weight. I was unable to investigate this potential selection bias because we did not collect any data for non-respondents. We tried to mitigate this in part by visiting schools in person during Term III (before the survey commenced in Term IV) to inform all Year 4 and 6 students that their data would be kept confidential and that all weight measurements would be recorded individually behind a private screen.

Summary of limitations

Table 8.1 summarises the main limitations of my thesis, where they occurred, what was done to limit their impact, and suggested methods for future research to limit their impact.

Table 8.1. Summary of study limitations and suggestions for future research

Limitation	Where in study	Study approach	Future research
Cross-sectional data	Study design	Analysis of associations rather than causality	Collect longitudinal and/or qualitative follow-up data
Sample size	Collection of data	Sample of 715 students in 34 schools	Even distribution and larger sample of students per school to incorporate MLM
Measurement bias	Accelerometery	600-minutes wear-time per day over any 3 days of the week	Investigate particular parts of the day/week, e.g. after-school hours, weekends
	SEIFA scores	Used student postcode	Include other factors in determining socio-economic status, e.g. household income, parental education
Selection bias	Selection of schools	Purposive sampling of at least 1 Govt. and 1 Private school in each Local Govt. Area (which were randomised)	Random sample of schools; capacity to include all schools within survey of any given LGA instead of aiming for just one in each LGA
	Selection of staff	Schools had final say on which staff would answer the BAEW questionnaire	Anonymous survey responses from staff members and/or collect responses from all staff
	Recruitment of students	All students were invited to participate per school (opt-in)	Opt-out recruitment
Reporting bias	Student self-report questionnaires	Self-report daily fruit and vegetable intake; self-report daily MVPA	Food diaries; repeated 24-hour recall; objective measures of reported behaviours through follow-up observational research
	BAEW questionnaire	Interview staff about obesogenicity of school environment	Objective measures of school environment; follow-up data; reliability and validity study of BAEW questionnaire
Multiple testing	Analysis	Multiple regression models	Larger samples can improve effect size measurements
Residual confounding	Final models	Incorporation of factors from many levels of influence into final models	Identify factors not included in final models; MLM to separate compositional and contextual factors

8.4 Taking this work forward through policy, practice and research

In the last two decades, the number of O&O children has increased threefold, and by 2011 approximately 25% of all Australian children were O&O.[11] What's more, the Victorian Government commissioned a study in 2008 that predicted the future prevalence of males and females aged 5-19 years in Victoria between 2005 and 2025 (both 21% in 2005). The final models estimated that child BMI would continue to increase for both sexes, and across the age span, without intervention — and that by 2025 one-third of all children and adolescents in Victoria would be O&O.[36] In response, the Australian government made childhood obesity a policy priority, with school-based interventions becoming the frontline for this government action. Schools have been said to play a role in childhood obesity prevention through focusing on healthy eating and an active lifestyle in their curriculum, policy and practices, environment, and school-to-community links.[52]

The increasing prevalence of childhood obesity has generated considerable media and political attention. According to Swinburn *et al.* (2008), it was only after the media started to regularly report on the childhood obesity epidemic – particularly between 2002-04 – that the Australian government started to consider more serious action. However, the precise size of the investment by federal and state governments into school-based interventions is difficult to estimate — financial data had not been pooled or were not publicly available. However, it was clear that the Australian government had invested hundreds of millions of dollars in the past decade to prevent childhood obesity using school-based interventions, which was despite a weak evidence-base in demonstrating the impact of these interventions. Difficult questions should be being asked at all levels of government about the cost-effectiveness of available solutions.

The Australian government can take stock by looking backwards; previous governments have at times made unpopular decisions for the betterment of the population's health, such as the enforcement of seatbelts in the 1980s or the plain-packaging of cigarettes in the 2000s. Popular or not, the majority of Australians are struggling today to live a healthy lifestyle and strong leadership is required to solve this enormous public health issue that is childhood obesity. In 2008, Swinburn recommended that Australian policy-makers focus a concerted effort on four broad areas, and I argue that these are still relevant:[194]

1) Leadership;
2) Advocacy for a multi-sector response;
3) Implementation of policies and laws to create healthier food and activity environments; and,
4) Increased and continued funding to reduce different obesogenic environments.

Going forward, and given the substantial investment by the governments into school-based interventions, it is vital that the Australian government understands the significance of gender differences in the planning of future obesity prevention efforts.[99,100] For instance, I have shown in my thesis that the schools doing more to promote healthy eating had lower rates of student zBMI — however, this was only found in female students. PA was also potentially more significant for male students, considering the links I found between student zBMI and rates of daily MVPA.

There is a big difference between a school ticking a box to say they will adopt a new healthy eating or PA policy, and actually implementing such a policy. Findings from my analysis showed a great deal of variation between schools — in 34 primary schools, the range of 33 environmental actions in place was fifteen, comparing the highest to lowest scores. A review by Nathan *et al.* (2015) on school-based policies, for example, has also highlighted an absence of information regarding the prevalence of school adoption for healthy eating and PA policies and practices.[195] Future research investigating the amount that schools are doing to promote healthy eating and PA will be improved by showing a causal link between school-based interventions and student weight outcomes. This can be achieved through a longitudinal approach and/or using qualitative follow-up data that would be built upon the motivations and influences of the school environment from the perspectives of students and school staff. Future research should also include validity and reliability studies of their measurement instruments, so that they can evaluate their programmes with more confidence.

8.5 Recommendations

Table 8.2 presents the key recommendations stemming from my thesis.

Table 8.2. Summary of key recommendations and assigned responsibility

#	Recommendations for future research, practice and policy	Responsibility of
1	Research instruments that have been used to investigate the school's impact on student obesity should be evaluated	Public health researchers
2	Gender differences should be an important factor in the development of any childhood obesity prevention programme	Public health researchers; policy-makers; school leadership; LGA leadership
3	Indigenous Australian children are at higher risk to obesity and more research is needed to improve our understanding of this area	Public health researchers; policy-makers; LGA leadership; Community Elders
4	Follow-up studies should evaluate the implementation of school-based obesity childhood prevention programmes	Public health researchers
5	Schools should invest in creating an environment that promotes healthy eating behaviours amongst students, particular for females	Public health researchers; policy-makers; school leadership; LGA leadership
6	The adoption of a socio-ecological framework can inform future research, policy, and practice concerning childhood obesity	Public health researchers; policy-makers; LGA leadership
7	Political leadership is required at all levels of government	Policy-makers; LGA leadership
8	Future research should look beyond the school setting to better understand the impact of the home environment and individual-level factors	Public health researchers
9	A replication of this study in other Australian states would support this research	Public health researchers
10	A repeat of this study with more objective measures of the school environmental actions to promote healthy eating and PA would allow more confidence over the school-level measures	Public health researchers
11	A large, longitudinal study looking at different school approaches to the promotion of healthy eating and PA amongst students would provide a more accurate indication of their effect, if present.	Public health researchers

8.6 Overall conclusions

Schools should always be a healthy place for children to be. My analysis supported the hypothesis that schools play an important role in childhood obesity. Amongst females, there was a significant difference in student zBMI between schools that did the most to promote healthy eating compared to schools that did the least. A range of individual-level factors were significantly associated with student zBMI. My thesis makes a unique contribution to the evidence-base and to the methodology behind the study of school effects on student weight outcomes. It promotes the adoption of a socio-ecological approach to childhood obesity prevention, focused across all levels of society, and it provides critical direction for future research and policy and legislation aimed at preventing childhood obesity in Australia and elsewhere.

Appendix One:

Copy of systematic review publication

Turner *et al. BMC Obesity* (2015) 2:13
DOI 10.1186/s40608-015-0045-5

BMC Obesity

RESEARCH ARTICLE Open Access

A systematic review of how researchers characterize the school environment in determining its effect on student obesity

Kyle Turner[1,2*], Charlie Foster[1,2], Steven Allender[3] and Emma Plugge[1]

Abstract

Background: Obesity in early childhood is a robust predictor of obesity later in life. Schools provide unparalleled access to children and have subsequently become major intervention sites. However, empirical evidence supporting the effectiveness of school-based interventions against childhood obesity is of limited scope and unknown quality. The aim of this systematic review is to critically assess how researchers have characterized the school environment in determining its effect on childhood weight status in order to improve the quality and consistency of research in this area. We conducted a narrative review with a systematic search of the literature in line with PRISMA guidelines (2009). Original peer-reviewed research articles in English were searched from Medline, EMBASE, CENTRAL, CINAHL and PsycINFO databases from earliest record to January 2014. We included empirical research that reported at least one measure of the primary/elementary school environment and its relationship with at least one objective adiposity-related variable for students aged 4–12 years. Two authors independently extracted data on study design, school-level factors, student weight status, type of analysis and effect.

Results: Five studies met the inclusion criteria. Each study targeted different parts of the school environment and findings across the studies were not comparable. The instruments used to collect school-level data report no validity or reliability testing.

Conclusions: Our review shows that researchers have used instruments of unknown quality to test if the school environment is a determinant of childhood obesity, which raises broader questions about the impact that schools can play in obesity prevention.

Keywords: School, Childhood obesity, Environmental measurement

Background

Obesity has risen dramatically since the 1980s in most developed nations [1]. The disease is acquired from a sustained positive energy imbalance, with poor eating and activity behaviors, genetic, behavioral, environmental, and economic factors contributing to its development [2]. Obesity is associated with an increased risk of diabetes, cardiovascular disease and certain cancers, as well as other negative health and social outcomes [3,4].

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Governments have focused prevention efforts on improved dietary and activity choices. These programmes particularly target children and adolescents, as obesity in youth is a robust predictor of adult obesity [5]. Schools provide unparalleled access to children and have therefore become the preferred setting for prevention strategies in the past few decades [3]. Empirical evidence, however, supporting the effectiveness of school-based interventions against childhood obesity is limited and of unknown quality.

Schools are well-defined environments that are hypothesized to influence student health outcomes by means of both compositional (which people are found in a place) and contextual factors (the characteristics of a place) [6]. In 2011, the Cochrane Collaboration reviewed school-based interventions that aimed to prevent childhood

Appendix Two:

Data extraction form and quality assessment results

DATA EXTRACTION FORM	
Study reference	Veugelers P and A Fitzgerald 2005. Effectiveness of school programs in preventing childhood obesity: A multilevel comparison. *American Journal of Public Health*. Vol. 95:3
Reference #	1
Journal of publication	American Journal of Public Health: Research and Practice
Date of publication	March 2005
Title of paper	Effectiveness of School Programs in Preventing Childhood Obesity: A Multilevel Comparison
Study design	Cross-sectional
Study objective	To evaluate the effectiveness of school programmes that aimed to prevent childhood overweight and obesity
Sampling/ randomization	Non-randomized. 282 of a total 291 public schools from the Nova Scotia province participated.
Response rate	51.1% RR
Study duration & dates	Data was collected in 2003. No seasonal information presented.
Location of study	Nova Scotia, Canada
# of participants by age and year level	5th Grade students. No age data presented.
# of schools & type	282 elementary schools
# of participants by gender	No gender-specific data presented.
Objectively measured student weight variables	Body mass index.
Obesity guidelines *(e.g. IOTF)*	IOTF
Age at which obesity outcome was measured	No age-specific data presented.
Instrument(s) used to assess school-level factors	Instrument has no citation or classification. No description of instrument presented other than stating that the study gathered information using a 'survey on general school characteristics with nutrition programmes'.
Validity and reliability	Not presented.
Who provided or collected information on school-level factors	School principal.

Reasoning for using this instrument	Not presented.

	Physical	***Economic***	***Policy***	***Socio-cultural***
Student-level outcome(s) investigated in relation to exposure			1. Student BMI.	
Factor(s) recorded in relation to the school-level exposure			1. A survey completed by the school principal asked whether or not they had policies or practices in place to offer healthy menu alternatives. No more detail is provided about the survey used to collect this information. A sub-sample of seven schools were reported to have implemented CDC recommendations in 1997 for school-based healthy eating programmes.	

School-level exposure(s) investigated			1. Presence or absence of a school nutrition programme.	

Definition of school environment according to authors	Public funded elementary schools.
Reasoning for targeting school-level exposure(s) according to authors	School-based healthy eating and physical activity programs provide a great opportunity to enhance the future health and well-being of children because they can reach almost all children and may (1) enhance learning and provide social benefits, (2) enhance health during critical periods of growth and maturation, (3) lower the risk for chronic diseases in adulthood, and (4) help to establish healthy behaviours at an early age that will lead to lifelong healthy habits. The effectiveness of school-based healthy eating and physical activity programmes is critical to evidence-based health policy and to justify broader implementation of successful programs. However, because only a limited number of studies have been conducted, and results have varied, the effectiveness of these programmes is not well established.
Limitation(s) of school-level measurement tool according to authors	Limitations of school-level data or measurement tool are not presented or discussed.
Limitation(s) of study design	Adjusted variables in analyses cannot exclude confounding through factors that were not considered. Response weights to overcome nonresponse bias were based on postal-code level of income. However, the software used by the authors did not allow for this adjustment in their multilevel logistic regression analysis.
Type of analysis used to investigate the school effect on student weight	Multilevel logistic regression

(e.g. multiple linear regression, multi-level)	
Reasoning for type of analysis	Reasoning for model not presented.
Adjusted variables	Gender, area of residence (urban or rural), parental education and income as first-level covariates, and neighborhood income as a second-level covariate.
Potential for same-source bias	Not presented.
Unadjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Effect of school nutrition programme on overweight: 0.91 (0.77, 1.09) Effect of CDC recommendations on overweight: 0.41 (0.32, 0.53)
Unadjusted odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Effect of school nutrition programme on obesity: 0.85 (0.63, 1.15) Effect of CDC recommendations on obesity: 0.28 (0.14, 0.57)
Standard Error for BMI-z score	N/A
Intra-class correlation	ICC not presented.
CONCLUSIONS	
Conclusions	Students from schools with a programme consistent with the CDC recommendations for school-based healthy eating programs exhibited substantially less overweight and obesity. However, students from schools that provided healthy menu alternatives did not have substantially healthier body weights than students from school without programmes.
Funding	This research was funded by the Canadian Population Health Initiative and a Canadian Institute of Health Research New Investigator Award.
Comments from authors	Thanks to participants and staff.
Further studies identified from references	None identified.

QUALITY ASSESSMENT			
Study Reference	1		
Title of paper	Effectiveness of School Programs in Preventing Childhood Obesity: A Multilevel Comparison		
Date of publication	March 2005		
Type of study	Cross-sectional evaluation		
Hypothesis/Aim/objective of the study clearly described	Yes		
SELECTION		***STARS***	***COMMENTS***
Characteristics of students included in study clearly defined	Cohort studies: inclusion/ exclusion criteria given * Case control: case definition given * No description of above		Inclusion and exclusion criteria not clearly defined. Age not presented.
Representativeness of the study participants	Yes representative * Potential for selection bias No description given		Response rate of 51.1% among students
Total stars allocated for selection (max 2)		0	
COMPARABILITY			
Comparability of cases + controls or cohorts on the basis of the design or analysis	Study controls for socio-economic status * Study controls for other potential confounding factors e.g. ethnicity * No controls undertaken or no adjustments attempted	*	Study attempts to control for SES factors
Non-response rate	Same for both groups * Non respondents described Rate different and no designation		Non-respondents are not clearly described.
Total starts allocated for comparability (max 3)		1	
EXPOSURE			
Ascertainment of exposure	Secure record * Structured interview (blinded to case/ control status) * Objectively measured * Interview not blinded Written self-report No description		No description of survey presented.
Same method of ascertainment for exposure	Yes * No	*	
Total stars allocated for exposure (max 2)		1	
OUTCOME			
Were the main obesity outcome measures used accurate (valid and reliable)	Yes * No	*	IOTF guidelines.

Assessment of outcome (overweight/ obesity)	Objectively measured assessment (e.g. BMI) ***** Record linkage (e.g. database records) ***** Self-report No description		
Total stars allocated for outcome (max 2)		1	
Additional comments			
Total Score	3/9		

** Adapted from: Newcastle Ottawa Quality Assessment Scale, 9 STARS AVAILABLE*

DATA EXTRACTION FORM	
Study reference	Fox M, A Dodd, A Wilson, P Gleason 2009. Association between school food environment and practices and body mass index of US public school children. *American Dietetic Association.* S108-17
Reference #	2
Journal of publication	American Dietetic Association
Date of publication	February 2009
Title of paper	Association between school food environment and practices and body mass index of US public school children
Study design	Cross-sectional
Study objective	To examine the association between school food environment and practices and child body mass index
Sampling/ randomization	Random, multistage sampling of approximately three schools (one elementary, one middle, and one secondary) from each school food authority within seven geographically distinct regions across the US. Approximately 10 children were randomly sampled from school lists in each school.
Response rate	Not presented in this publication.
Study duration & dates	January – June 2005
Location of study	United States
# of participants by age and year level	2,228 students in Grade 1-12
# of schools & type	287 public schools (elementary, middle, and secondary)
# of participants by gender	No gender-specific data presented.
Objectively measured student weight variables	Body mass index.
Obesity guidelines *(e.g. IOTF)*	US Centers for Disease Control and Prevention BMI-for-age percentiles, or the binary BMI variable 'obese' (above 95^{th} percentile) or 'not-obese'.
Age at which obesity outcome was measured	No age-specific data presented.

Instrument(s) used to assess school-level factors	Instrument has no citation or classification. 1. The authors describe the instrument as a 'menu survey' that that provided information about the foods offered in school meals each day during a specified "target week." 2. School food authority directors, school foodservice managers, and principals also completed brief surveys that provided information about foodservice operations and practices, nutrition education and promotion practices, and whether the school had an open campus policy. 3. In addition, trained data collectors completed observation checklists that documented the competitive food sources available in each school and, for each major source of competitive foods (à la carte, vending machines, school stores, snack bars, food carts, and other sources), documented the specific types of food that were offered.
Validity and reliability	Not presented.
Who provided or collected information on school-level factors	1-2. Foodservice managers; 2. Principals, school food authority directors; and, 3. Trained data collectors.
Reasoning for using this instrument	The authors state that previous researchers used data from these information collected with these three instruments to develop measures that characterized food environments and practices in each school. These existing measures were used, in some cases with minor adjustments, in this analysis. No justification is provided for why minor adjustments were made.

	Physical	***Economic***	***Policy***	***Socio-cultural***
Student-level outcome(s) investigated in relation to exposure			1-5. BMI-for-age percentiles, and binary BMI variable 'obese' (above 95th percentile) or 'not-obese'.	

Factor(s) recorded in relation to the school-level exposure			1. LNED includes: sugar-sweetened beverages (carbonated soft drinks, fruit-flavoured juice drinks, lemonades, sweetened teas, and “energy” or sport drinks), chips (regular, not lower-/reduced-fat), cookies, ice cream, cake-type desserts, muffins (regular, not lower-fat), pastries, doughnuts, crispy rice bars, candy, energy bars, fruit snacks, French fries (all types), and similar potato products, such as potato puffs; and, 2-5. Based on information from menu surveys completed by school foodservice managers.	
School-level exposure(s) investigated			1. Low-nutrient, energy-dense (LNED) foods available á la carte in school cafeteria; 2. Whole or 2% milk offered in school cafeteria; 3. Fresh fruit/ raw vegetables not offered daily in school lunches; 4. French fries/ similar products offered more than once per week in school lunches; and, 5. Dessert offered more than once per week in school lunches.	

Definition of school environment according to authors	Public funded elementary, middle or high school (Grade 1-12)
Reasoning for targeting school-level exposure(s) according to authors	Despite widespread interest in leveraging school environments and policies to address the problem of childhood obesity, there is little information available about whether such policies are effective and, if they are, which ones have the greatest potential to affect children’s diets and thereby prevent or reduce obesity.
Limitation(s) of school-level measurement tool according to authors	School-level data were self-reported by school foodservice managers.
Limitation(s) of study design	Due to the cross-sectional study design, it is not possible to conclusively attribute associations between characteristics of school food environments and practices and student BMI.
Type of analysis used to investigate	Ordinary-least-squares regression model to estimate the relationships between school food environments and practices and BMI-z score. For the

the school effect on student weight *(e.g. multiple linear regression, multi-level)*	binary variable that measures whether a child was obese, the authors used a comparable logistic regression model.
Reasoning for type of analysis	The authors used the ordinary-lest-squares regression model because BMI-z is a continuous variable. No other reasoning is presented.
Adjusted variables	Statistical models controlled for family usual dining habits, child's self-reported physical activity levels, parent's assessment of child's physical activity levels relative to other children, child's screen time.
Potential for same-source bias	Not presented.
Unadjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Not presented.
Unadjusted odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted Odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	1. Low-nutrient, energy-dense (LNED) foods available á la carte in school cafeteria = 1.09 (0.57 – 2.08); 2. Whole or 2% milk offered in school cafeteria = 1.17 (0.75 – 1.82); 3. Fresh fruit/ raw vegetables not offered daily in school lunches = 1.13 (0.73 – 1.75); 4. French fries/ similar products offered more than once per week in school lunches = 2.70 (1.58 – 4.62); and, 5. Dessert offered more than once per week in school lunches = 1.78 (1.13 – 2.80)
Standard Error for BMI-z score	1. Low-nutrient, energy-dense (LNED) foods available á la carte in school cafeteria = -0.15 (0.11); 2. Whole or 2% milk offered in school cafeteria = -0.13 (0.10); 3. Fresh fruit/ raw vegetables not offered daily in school lunches = 0.19 (0.09); 4. French fries/ similar products offered more than once per week in school lunches = 0.20 (0.10); and, 5. Dessert offered more than once per week in school lunches = 0.08 (0.08)
Intra-class correlation	Not presented.
CONCLUSIONS	
Conclusions	Policies that school administrators and others interested in potentially controlling children's BMI and in improving children's overall diet quality may want to consider limiting French fries and desserts in school lunches and limiting children's access to LNED foods through vending machines.
Funding	This research was funded by the Robert Wood Johnston Foundation (57930).

Comments from authors	No comments.
Further studies identified from references	None identified.

QUALITY ASSESSMENT			
Study Reference	2		
Title of paper	Association between school food environment and practices and body mass index of US public school children		
Date of publication	February 2009		
Type of study	Cross-sectional examination		
Hypothesis/Aim/objective of the study clearly described	Yes		
SELECTION		***STARS***	***COMMENTS***
Characteristics of students included in study clearly defined	Cohort studies: inclusion/ exclusion criteria given ***** Case control: case definition given ***** No description of above	*	Detailed demographic information provided for sample.
Representativeness of the study participants	Yes representative ***** Potential for selection bias No description given	*	National random sample.
Total stars allocated for selection (max 2)		2	
COMPARABILITY			
Comparability of cases + controls or cohorts on the basis of the design or analysis	Study controls for socio-economic status ***** Study controls for other potential confounding factors e.g. ethnicity ***** No controls undertaken or no adjustments attempted	*	Attempts to control for multiple SES and other factors.
Non-response rate	Non-respondents described* Rate different and no designation		Non-respondents are not described.
Total starts allocated for comparability (max 3)		1	
EXPOSURE			
Ascertainment of exposure	Secure record ***** Structured interview (blinded to case/ control status) ***** Objectively measured * Interview not blinded Written self-report No description		Self-report survey completed by foodservice manager.
Same method of ascertainment for exposure	Yes ***** No	*	
Total stars allocated for exposure (max 2)		1	
OUTCOME			

Were the main obesity outcome measures used accurate (valid and reliable)	Yes * No	*	CDC reference
Assessment of outcome (overweight/ obesity)	Objectively measured assessment (e.g. BMI) * Record linkage (e.g. database records) * Self-report No description	*	US Centers for Disease Control and Prevention BMI-for-age percentiles, or the binary BMI variable 'obese' (above 95th percentile) or 'not-obese'
Total stars allocated for outcome (max 2)		2	
Additional comments			
Total Score	6/9		

** Adapted from: Newcastle Ottawa Quality Assessment Scale, 9 STARS AVAILABLE*

DATA EXTRACTION FORM	
Study reference	Harrison F, G Bentham, A Jones, A Cassidy, E van Sluijs, S Griffin 2011. School level correlates with adiposity in 9-10 year old children. *Health & Place*. Vol. 17: 710-16
Reference #	3
Journal of publication	Health & Place
Date of publication	January 2011
Title of paper	School level correlates with adiposity in 9-10 year old children
Study design	Cross-sectional.
Study objective	To identify associations between the physical, social and policy environments of schools and adiposity in 9-10 year old children in Norfolk, UK.
Sampling/ randomization	Invitations to participate in the study were randomly sent to 157 of 227 eligible state and independent schools across Norfolk with at least 12 Grade 5 students. Participating schools were then stratified by rural/ urban status, with rural schools oversampled.
Response rate	58.5%
Study duration & dates	Not presented.
Location of study	Norfolk, United Kingdom.
# of participants by age and year level	1,724 eligible participants in Grade 5
# of schools & type	92
# of participants by gender	959 girls, 765 boys
Objectively measured student weight variables	1. Fat Mass Index; 2. Body Mass Index

Obesity guidelines *(e.g. IOTF)*	1. Tyrell *et al.* 2001; 2. IOTF
Age at which obesity outcome was measured	9-10 years
Instrument(s) used to assess school-level factors	Instruments have no citation or classification. 1. The school environment questionnaire was designed specifically for this study. 2.
Validity and reliability	1. Not presented; 2. The authors' state that the audit tool was based on previously validated tools (Cardon *et al*. 2008; Hillsdon *et al*. 2006); and, 3. Not presented.
Who provided or collected information on school-level factors	1. Questionnaire completed by the head teacher; 2. An audit of the school grounds undertaken by a trained assessor; and, 3. General information was supplied by Norfolk County Council for state schools, whereas similar information for independent schools was provided by the Independent Schools Council or the schools themselves.
Reasoning for using this instrument	1-3. Not presented.

	Physical	***Economic***	***Policy***	***Socio-cultural***
Student-level outcome(s) investigated in relation to exposure	4. Question: cycle provision score? – Fat Mass Index (results presented for girls only)		3. Question: whether children can eat any food they like during break-time? – Fat Mass Index (results presented for boys only)	

Factor(s) recorded in relation to the school-level exposure	4. In total, 44 items recorded about school access points and transport infrastructure around them, presence and quality of various structures, suitability of grounds for sports, informal games and general play, general aesthetic indicators.	5. (%) of children eligible for free school meals	1. Access/ quality of PA facilities, hours of PE, swimming lessons, provision of extracurricular PA. 2. Facilities and time provision. 3. PA and healthy eating promotion, break-time policies, active travel facilities and policies, health education. 6. Whether or not school participated in the HS programmes	
School-level exposure(s) investigated	4. Suitability of school grounds for PA.	5. Free school meals.	1. Physical activity (PA) opportunities at school. 2. Food-related learning opportunities. 3. School rules & attitudes. 6. The 'Healthy School' programmes (UK Govt).	

Definition of school environment according to authors	State and independent schools from Norfolk, UK.
Reasoning for targeting school-level exposure(s) according to authors	Despite a growing number of studies examining the relationship between children's adiposity and elements of the school environment, it remains unclear as to which aspects of the environment are most important. Various aspects of the physical, social, and policy environment at school may impact on both food consumption and physical activity.
Limitation(s) of school-level measurement tool	A limitation considered by the authors was the banding together of categorical school level variables into tertiles. NOTE: The authors view the wide range of school environment variables recorded as a strength and do not report any limitations in regards to this facet of the study.

according to authors	
Limitation(s) of study design	Due to the cross-sectional study design, it is not possible to conclusively attribute associations between characteristics of school food environments and practices and student FMI. Foot-to-foot bioelectrical impedance measures of body fat do not measure the composition of the upper body. Children also did not fast prior to impedance measures and the test was only performed once. The Norfolk-area has a low proportion of non-White pupils.
Type of analysis used to investigate the school effect on student weight *(e.g. multiple linear regression, multi-level)*	Multivariable regression models of log-transformed FMI for boys and girls.
Reasoning for type of analysis	A multi-level model was used to take account of the hierarchical structure of the dataset, with student FMI the outcome variable at level one, and school data at level two. FMI was log-transformed because its distribution was skewed.
Adjusted variables	FMI was adjusted for individual and family correlates, including: covariates age, maternal BMI, age parent left full-time education, household access to cars, home tenure, and school urban/ rural status. Variables were removed using a backwards stepwise procedure so that only those statistically significant at *p* <0.1 remained.
Potential for same-source bias	Not presented.
Unadjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Not presented.
Unadjusted odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted Odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Not presented.
Standard Error for BMI-z score	N/A
Intra-class correlation	When covariates were added, the ICC for girls was less than 0.1%, and for boys, 0.17 - 0.81%.

CONCLUSIONS	
Conclusions	Overall, this study found that rather few school-related factors were associated with adiposity in 9–10 year old children from Norfolk, UK.
Funding	This research was funded by UK National Prevention Research Initiative.
Comments from authors	Thanks to participants and staff.
Further studies identified from references	None identified.

QUALITY ASSESSMENT			
Study Reference	3		
Title of paper	School level correlates with adiposity in 9-10 year old children		
Date of publication	January 2011		
Type of study	Cross-sectional examination		
Hypothesis/Aim/objective of the study clearly described	Yes		
SELECTION		***STARS***	***COMMENTS***
Characteristics of students included in study clearly defined	Cohort studies: inclusion/ exclusion criteria given ***** Case control: case definition given ***** No description of above	*	Detailed description of participants presented.
Representativeness of the study participants	Yes representative ***** Potential for selection bias No description given		Poor heterogeneity of participants within Norfolk area.
Total stars allocated for selection (max 2)		1	
COMPARABILITY			
Comparability of cases + controls or cohorts on the basis of the design or analysis	Study controls for socio-economic status ***** Study controls for other potential confounding factors e.g. ethnicity ***** No controls undertaken or no adjustments attempted	*	Study controls for several factors, but these were mostly self-reported.
Non-response rate	Same for both groups ***** Non respondents described Rate different and no designation		Non-respondents are not described.
Total starts allocated for comparability (max 3)		1	
EXPOSURE			
Ascertainment of exposure	Secure record ***** Structured interview (blinded to case/ control status) ***** Objectively measured * Interview not blinded Written self-report No description		Measures of exposure lacked any validity and reliability testing.

Same method of ascertainment for exposure	Yes * No	*	Exposure measurements differed between school types.
Total stars allocated for exposure (max 2)		1	
OUTCOME			
Were the main obesity outcome measures used accurate (valid and reliable)	Yes * No	*	FMI results correlated highly with BMI, which used IOTF guidelines.
Assessment of outcome (overweight/ obesity)	Objectively measured assessment (e.g. BMI) * Record linkage (e.g. database records) * Self-report No description	*	Results were objectively measured.
Total stars allocated for outcome (max 2)		2	
Additional comments			
Total Score	5/9		

** Adapted from: Newcastle Ottawa Quality Assessment Scale, 9 STARS AVAILABLE*

DATA EXTRACTION FORM	
Study reference	Rundle A, C Richards, M Bader, O Schwartz-Soicher, K Lee, J Quinn, G Lovasi, C Weiss, K Neckerman 2012. Individual- and School-Level Sociodemographic Predictors of Obesity Among New York City Public School Children. *American Journal of Epidemiology*. Vol. 176:11
Reference #	4
Journal of publication	American Journal of Epidemiology
Date of publication	March 2012
Title of paper	Individual- and School-Level Sociodemographic Predictors of Obesity Among New York City Public School Children
Study design	Cross-sectional
Study objective	To identify individual- and school-level sociodemographic characteristics associated with overweight and obesity among public school students in New York, US.
Sampling/ randomization	The NYC Department of Education (DoE) annually collects student height, weight, fitness, sex, age, and school identification data through their NYC Fitnessgram Program. Sociodemographic data for all participating students were obtained from a separate data set at the NYC DoE. Special education students were excluded.
Response rate	67.5%
Study duration & dates	Across the 2007-08 school year.
Location of study	New York City, US.
# of participants by age and year level	624,204 total participants from kindergarten to Grade 12 (336,771 from elementary).
# of schools & type	1,276 elementary, middle and high schools.

# of participants by gender	Elementary school: 164,915 girls, 171,856 boys.
Objectively measured student weight variables	Body Mass Index, BMI-z score.
Obesity guidelines *(e.g. IOTF)*	CDC
Age at which obesity outcome was measured	Not presented.
Instrument(s) used to assess school-level factors	NYC DoE school enrolment database.
Validity and reliability	Not presented.
Who provided or collected information on school-level factors	Not presented.
Reasoning for using this instrument	Not presented.

	Physical	***Economic***	***Policy***	***Socio-cultural***
Student-level outcome(s) investigated in relation to		Body Mass Index.		Body Mass Index.

Factor(s) recorded in relation to the school-level exposure		1. Four categories of school lunch pricing were used as a measure of SES: 1) NYC Human Resources Administration free lunch, provided to children whose families participate in Temporary Assistance for Needy Families or the Supplemental Nutrition Assistance Program or who attend school in an impoverished area; 2) form-based free lunch, obtained by parents applying to the school and qualifying based on income; 3) form-based reduced-price lunch, obtained through the same application process as for form-based free lunch; and, 4) full-price lunch.		2. % US-born. 3. % of black students. 4. % of Hispanic students.
School-level exposure(s) investigated		1. School lunch pricing.		2-4. Ethnicity of students.
Definition of school environment according to authors	Elementary schools were defined as being grades kindergarten through 5, middle school children as being in grades 6-8, and high school children as being in grades 9-12.			
Reasoning for targeting school-level exposure(s) according to authors	Not presented.			
Limitation(s) of school-level measurement tool	None presented.			

according to authors	
Limitation(s) of study design	The exclusion of private schools. BMI was only measured at schools with PE programmes. Participation was not uniform across sociodemographic populations. Underrepresentation of lower-SES groups. Cross-sectional study design.
Type of analysis used to investigate the school effect on student weight *(e.g. multiple linear regression, multi-level)*	Multivariable generalized estimating equations with a logit link were used to calculate odds ratios (95% CI) for associations between body size category (normal-weight vs. obese, and normal-weight vs. overweight) and individual-level sociodemographic characteristics and school-level compositional characteristics.
Reasoning for type of analysis	No specific reference as to why they used this model. The authors do state that data were stratified by sex because prior analyses of elementary school children in NYC suggested that racial/ethnic differences in obesity prevalence differed by sex.
Adjusted variables	The authors only state that final models were adjusted for 'individual-level sociodemographic variables'.
Potential for same-source bias	Not presented.
Unadjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	School lunch pricing (**P* < 0.05): Foy boys – 1. Full price OR 1.00; 2. HRA free meal OR 1.07* (1.01,1.13); 3. Form-based free meal OR 1.14* (1.08-1.19); 4. Reduced-price meal OR 1.15* (1.08-1.23). Foy girls – 1. Full price OR 1.00; 2. HRA free meal OR 1.04 (0.98,1.10); 3. Form-based free meal OR 1.05 (0.99-1.11); 4. Reduced-price meal OR 1.04 (0.97-1.11).
Unadjusted odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted Odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	School lunch pricing (**P* < 0.05): Foy boys – 1. Full price OR 1.00; 2. HRA free meal OR 1.17* (1.11,1.24); 3. Form-based free meal OR 1.20* (1.14,1.26); 4. Reduced-price meal OR 1.23* (1.16,1.31). Foy girls – 1. Full price OR 1.00; 2. HRA free meal OR 1.17* (1.11,1.24); 3. Form-based free meal OR 1.15* (1.09,1.21); 4. Reduced-price meal OR 1.19* (1.11,1.28).
Standard Error for BMI-z score	Not presented.
Intra-class correlation	Not presented.
CONCLUSIONS	

Conclusions	School-level SES and immigrant composition are associated with student obesity in New York City.
Funding	This research was funded by Robert Wood Johnson Active Living Research Program Round 8 Grant.
Comments from authors	N/A
Further studies identified from references	None identified.

QUALITY ASSESSMENT			
Study Reference	4		
Title of paper	Individual- and School-Level Sociodemographic Predictors of Obesity Among New York City Public School Children		
Date of publication	March 2012		
Type of study	Cross-sectional examination		
Hypothesis/Aim/objective of the study clearly described	Yes		
SELECTION		***STARS***	***COMMENTS***
Characteristics of students included in study clearly defined	Cohort studies: inclusion/ exclusion criteria given ***** Case control: case definition given ***** No description of above		
Representativeness of the study participants	Yes representative ***** Potential for selection bias No description given		Large data set, but private schools were excluded.
Total stars allocated for selection (max 2)		0	
COMPARABILITY			
Comparability of cases + controls or cohorts on the basis of the design or analysis	Study controls for socio-economic status ***** Study controls for other potential confounding factors e.g. ethnicity ***** No controls undertaken or no adjustments attempted	*	Controls for individual-level sociodemographic information.
Non-response rate	Non-respondents described* Rate different and no designation		Little information on non-participants.
Total starts allocated for comparability (max 3)		1	
EXPOSURE			
Ascertainment of exposure	Secure record ***** Structured interview (blinded to case/ control status) ***** Objectively measured * Interview not blinded Written self-report No description	*	No information provided on how enrolment data are collected.
Same method of ascertainment for exposure	Yes ***** No	*	
Total stars allocated for exposure (max 2)		2	

OUTCOME			
Were the main obesity outcome measures used accurate (valid and reliable)	Yes ***** No	*	
Assessment of outcome (overweight/ obesity)	Objectively measured assessment (e.g. BMI) ***** Record linkage (e.g. database records) ***** Self-report No description	*	BMI
Total stars allocated for outcome (max 2)		2	
Additional comments			
Total Score	5/9		

** Adapted from: Newcastle Ottawa Quality Assessment Scale, 9 STARS AVAILABLE*

DATA EXTRACTION FORM	
Study reference	Leatherdale S, 2013. A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 – 4 students. *BMC Public Health*. Vol. 13:982
Reference #	5
Journal of publication	BMC Public Health
Date of publication	October 2013
Title of paper	A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 – 4 students
Study design	Cross-sectional
Study objective	To examine if school-based physical activity policies and the built environment surrounding a school are associated with weight status among children.
Sampling/ randomization	Cross-sectional data were collected from a convenience sample of grade 1 to 4 students attending 30 elementary schools
Response rate	59.4%
Study duration & dates	2007-08
Location of study	Ontario, Canada.
# of participants by age and year level	2,331 grade 1 – 4 students.
# of schools & type	30 elementary schools.
# of participants by gender	1,187 boys, 1,139 girls.
Objectively measured student weight variables	Body Mass Index.
Obesity guidelines *(e.g. IOTF)*	IOTF
Age at which obesity outcome was measured	No age-specific data presented.

Instrument(s) used to assess school-level factors	1. Physical Activity Module of the Healthy School Planner (HSP-PAM) 2. Enhance Points of Interest (EPOI)
Validity and reliability	Not presented.
Who provided or collected information on school-level factors	1. "The senior administrator(s) most knowledgeable about the school's policies and resources" completed the HSP-PAM. 2. Not presented.
Reasoning for using this instrument	1. The HSP-PAM is a tool designed to assess policies, activities, committees, facilities and guidelines surrounding PA in the school environment. 2. The EPOI is a data file in a database of the type and location of different opportunity structures within the built environment (recreation facilities, variety stores, fast-food restaurants).

	Physical	***Economic***	***Policy***	***Socio-cultural***
Student-level outcome(s) investigated in relation to	1-2. BMI (overweight vs. normal weight)		3-7. BMI (overweight vs. normal weight)	8-14. BMI (overweight vs. normal weight)

Factor(s) recorded in relation to the school-level exposure	1. Student access to a variety of facilities on and off school grounds during school hours 2. Availability of physical activities during inclement weather		3. Support for active transportation to and from school 4. Implementation of daily PA 5. Time spent per week engaged in PA during physical education classes 6. Classes taught by a qualified physical education specialist 7. Consistency of intramural programming across grade divisions and seasons	8. Emphasis placed on maximizing participation in PA through school programs 9. Incorporation of PA into other school subjects 10. Special recognition of students who participate in school physical activities 11. Formal collection of suggestions from the school community about PA at school 12. Promotion of PA programs and events for students, families and school staff 13. Use of PA as a reward, not as discipline 14. Presence of written policies or practices that support PA
School-level exposure(s) investigated	Healthy physical environment		Instructions and programmes	Supportive social environment

Definition of school environment according to authors	Elementary school in Ontario, Canada.
Reasoning for targeting school-level exposure(s) according to authors	Ecological models suggest that weight status would not just be determined by individual characteristics alone, but also by the characteristics of the environmental context (e.g., school) in which that individual is situated. Given the lack of evidence exploring (a) the importance of the school environment on weight status among younger children, and (b) how PA policies within the school environment are associated with weight status, there remains an important gap in the literature. The association between the built environment and youth overweight is also often overlooked in research.

Limitation(s) of school-level measurement tool according to authors	Not presented.
Limitation(s) of study design	Cross-sectional study design. No data on energy-intake included in model. No data on food policies within the school environment. Did not adjust for any school-based programmes or interventions in place.
Type of analysis used to investigate the school effect on student weight *(e.g. multiple linear regression, multi-level)*	Multi-level logistic regression.
Reasoning for type of analysis	Since students (level-1) are nested within schools (level-2), the authors chose to perform two series of multi-level logistic regression analyses to examine characteristics associated with being (1) overweight versus a normal weight, and (2) obese versus a normal weight.
Adjusted variables	BMI adjusted for age and sex.
Potential for same-source bias	Not presented.
Unadjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted odds ratio for overweight ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Statistically significant findings: 1. Student access to a variety of facilities on and off school grounds during school hours: *Initiation* 1.00; *Action* 0.39 (0.16, 0.92)** *Maintenance* 0.32 (0.12, 0.86)** 3. Support for active transportation to/ from school: *Initiation* 1.00; *Action* 0.72 (0.36, 1.42); *Maintenance* 0.47 (0.22, 0.98)* (* = P <.05; ** = P <.0)
Unadjusted odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value)	Not presented.
Adjusted Odds ratio for obesity ($\sigma^2_{\mu 0}$ = 95% CI *p*-value) *factors adjusted for*	Not presented.
Standard Error for BMI-z score	N/A
Intra-class correlation	There was significant between-school random variation in the odds of a student being overweight ($\sigma^2_{\mu 0}$ = 0.274(0.106), p < 0.001). The two school-level characteristics (1. and 3.) explained 7.3% of the between-school variability in overweight.

CONCLUSIONS	
Conclusions	Obesity prevention efforts should perhaps target schools that do not provide student access to recreation facilities during school hours, or schools that do not support active transportation for students.
Funding	This research was funded by the Heart and Stroke Foundation of Ontario.
Comments from authors	N/A
Further studies identified from references	None identified.

QUALITY ASSESSMENT			
Study Reference	5		
Title of paper	A cross-sectional examination of school characteristics associated with overweight and obesity among grade 1 – 4 students		
Date of publication	October 2013		
Type of study	Cross-sectional examination		
Hypothesis/Aim/objective of the study clearly described	Yes		
SELECTION		***STARS***	***COMMENTS***
Characteristics of students included in study clearly defined	Cohort studies: inclusion/ exclusion criteria given ***** Case control: case definition given ***** No description of above		Poor description of participants.
Representativeness of the study participants	Yes representative ***** Potential for selection bias No description given		Not enough information to know.
Total stars allocated for selection (max 2)		0	
COMPARABILITY			
Comparability of cases + controls or cohorts on the basis of the design or analysis	Study controls for socio-economic status ***** Study controls for other potential confounding factors e.g. ethnicity ***** No controls undertaken or no adjustments attempted		Study only adjusts BMI for age and sex.
Non-response rate	Non-respondents described* Rate different and no designation		Poor description of non-respondents.
Total starts allocated for comparability (max 3)		0	
EXPOSURE			
Ascertainment of exposure	Secure record ***** Structured interview (blinded to case/ control status) ***** Objectively measured * Interview not blinded Written self-report No description		Little information provided on data collection methodology for school-level data.
Same method of ascertainment for exposure	Yes ***** No	*	

Total stars allocated for exposure (max 2)		0	
OUTCOME			
Were the main obesity outcome measures used accurate (valid and reliable)	Yes ***** No	*	Not presented.
Assessment of outcome (overweight/ obesity)	Objectively measured assessment (e.g. BMI) ***** Record linkage (e.g. database records) ***** Self-report No description		
Total stars allocated for outcome (max 2)		1	
Additional comments			
Total Score	2/9		

** Adapted from: Newcastle Ottawa Quality Assessment Scale, 9 STARS AVAILABLE*

Appendix Three:

Be Active Eat Well questionnaire

Primary School – Environmental Audit

Complete the following questionnaire by gaining consensus responses from 2-4 staff members at the school, ideally: the school principal, a physical education teacher, and a member of the school food service. Read out the questions and allow the school staff members to discuss their answer and reach a consensus. The interview normally takes about 15-20 minutes.

SECTION A: SCHOOL DEMOGRAPHICS

1. Date (*dd/mm/yyyy*): _____/_____/______

2. School Name: ______________________________________

3. School Postcode: _____________

4. What are the staff positions of those taking part in this interview *(multi-response)*?

School Principal	◻
Vice Principal	◻
P/E Teacher	◻
Food service	◻
Other	◻

5. School Year Level *(e.g. Primary, Secondary, Prep-12)*:

____

6. School Gender *(e.g. Co-ed, All girls, All boys)*:

____

7. School Type *(e.g. Government, Catholic, Independent)*:

____

SECTION B: INTERNAL CANTEEN SERVICE

8. Does your school currently have an Internal Canteen Service where children order foods and beverages that are supplied by a school canteen? This does not include externally operated food service providers.

Yes □ No □ Unsure □

***IF NO, go to Section C**

9. Does the canteen service have a breakfast program before school?

Yes □ No □ Unsure □

10. **IF YES**, how many days per week? ___________________

Are the following foods and beverages available from the school canteen?

11.	Fruit:	Yes □	No □
12.	Milk *(full fat)*:	Yes □	No □
13.	Milk *(low fat)*:	Yes □	No □
14.	Yoghurt *(full fat)*:	Yes □	No □
15.	Yoghurt *(low fat)*:	Yes □	No □
16.	Filled Rolls/ Sandwiches:	Yes □	No □
17.	Lollies/ Chocolate:	Yes □	No □
18.	Hot Chips:	Yes □	No □
19.	Crisps:	Yes □	No □
20.	Pies:	Yes □	No □
21.	Carbonated Drinks:	Yes □	No □
22.	Fruit Juice *(100%)*:	Yes □	No □
23.	Fruit Drink:	Yes □	No □
24.	Energy Drink:	Yes □	No □

25. Is making a profit for the school an important part of the canteen service?

Yes □ No □ Unsure □

26. Is the canteen service contracted to a commercial operator?

Yes □ No □ Unsure □

27. How adequate is the space in the canteen for food preparation?

Very Inadequate □
Inadequate □

Unsure □
Adequate □
Very Adequate □

28. Indicate your level of agreement or disagreement with the following statement:

"Our canteen service mainly provides foods with high nutritional value."

Strongly disagree □
Disagree □
Neither □
Agree □
Strongly agree □

29. Does the canteen have a pricing policy that encourages the sale of healthy food choices at reduced cost?

Yes □ No □ Unsure □

30. Does the canteen routinely promote and advertise healthy food choices *(e.g. highlighted healthy foods on menu, offer taste-testing opportunities for new food)*?

Yes □ No □ Unsure □

31. **IF YES**, describe the type of promotion/ advertisement:

____
____

32. Is the canteen menu reviewed on a regular basis?

Yes □ No □ Unsure □

33. **IF YES**, who reviews the menu?

____

34. Do the foods provided by the canteen service reflect classroom food and nutrition messages?

Fully □ Partially □ Not at all □ Unsure □

SECTION C: EXTERNAL FOOD SERVICE

35. Does your school currently have an External Food Service where children order foods and beverages that are supplied by an external provider? *(This is distinct from an internally operated food service)*.

Yes ◻ No ◻ Unsure ◻

***IF NO, go to Section D**

36. Does the external food service have a breakfast program before school?

Yes ◻ No ◻ Unsure ◻

37. **IF YES**, how many days per week? ___________________

Are the following foods and beverages available from the external food service?

38.	Fruit:	Yes ◻	No ◻
39.	Milk *(full fat)*:	Yes ◻	No ◻
40.	Milk *(low fat)*:	Yes ◻	No ◻
41.	Yoghurt *(full fat)*:	Yes ◻	No ◻
42.	Yoghurt *(low fat)*:	Yes ◻	No ◻
43.	Filled Rolls/ Sandwiches:	Yes ◻	No ◻
44.	Lollies/ Chocolate:	Yes ◻	No ◻
45.	Hot Chips:	Yes ◻	No ◻
46.	Crisps:	Yes ◻	No ◻
47.	Pies:	Yes ◻	No ◻
48.	Carbonated Drinks:	Yes ◻	No ◻
49.	Fruit Juice *(100%)*:	Yes ◻	No ◻
50.	Fruit Drink:	Yes ◻	No ◻
51.	Energy Drink:	Yes ◻	No ◻

52. Is making a profit for the school an important part of the external food service?

Yes ◻ No ◻ Unsure ◻

53. Is the external food service contracted to a commercial operator?

Yes ◻ No ◻ Unsure ◻

54. Indicate your level of agreement or disagreement with the following statement:

"Our external food service mainly provides foods with high nutritional value."

Strongly disagree □
Disagree □
Neither □
Agree □
Strongly agree □

55. Does the external food service have a pricing policy that encourages the sale of healthy food choices at reduced cost?

Yes □ No □ Unsure □

56. Does the external food service routinely promote and advertise healthy food choices *(e.g. highlighted healthy foods on menu, offer taste-testing opportunities for new food)*?

Yes □ No □ Unsure □

57. **IF YES**, describe the type of promotion/ advertisement:

____
____

58. Is the external food service menu reviewed on a regular basis?

Yes □ No □ Unsure □

59. **IF YES**, who reviews the menu?

____

60. Do the foods provided by the canteen service reflect classroom food and nutrition messages?

Fully □ Partially □ Not at all □ Unsure □

SECTION D: SCHOOL FOOD & NUTRITION POLICIES

61. Does your school have a written policy or policies promoting Healthy Eating?

Yes □ No □

***IF NO, go to Section E**

62. How many policies do you have in place? _______________

Does this policy (or policies) include:

63. What foods are made available in the canteen? Yes □ No □
64. The availability of water? Yes □ No □
65. Restricting access to stores and food outlets? Yes □ No □
66. Vending machines at school? Yes □ No □
67. Food association with fundraising? Yes □ No □
68. Food association with special events *(e.g. Sports Day)*? Yes □ No □
69. Setting aside adequate time for children to eat lunch? Yes □ No □
70. The type of food that may be brought from home? Yes □ No □
71. Teaching focusing on food and nutrition in the curriculum? Yes □ No □
72. Distribution of information to parents about healthy food and eating? Yes □ No □
73. Staff acting as role models in the area of healthy eating? Yes □ No □
74. Encouraging children to adopt healthy eating behaviours? Yes □ No □
75. Operating the school food service not for profit? Yes □ No □
76. Using food as a reward *(e.g. chocolate frogs, lollies)*? Yes □ No □

77. How effective have the policies been on overall healthy eating?

Very Effective □ Moderately Effective □ Not Effective □

78. What proportion of teachers do you think are aware of these healthy eating policies?

All □
Most □
Half □
Very few □
None □

SECTION E: THE NUTRITION ENVIRONMENT

79. Rate the level of priority for *nutrition* at your school?

Very Poor □
Poor □
Moderate □
Good □
Very Good □

80. Rate your school's practices and policies for the promotion of healthy eating?

Very Poor ☐
Poor ☐
Moderate ☐
Good ☐
Very Good ☐

81. Rate the extent to which teachers at your school act as role models by eating healthy foods?

Very Poor ☐
Poor ☐
Moderate ☐
Good ☐
Very Good ☐

82. Rate the promotion of healthy foods at your school's social/ sporting events?

Very Poor ☐
Poor ☐
Moderate ☐
Good ☐
Very Good ☐

83. Rate the level of support for healthy eating provided by parents at your school?

Very Poor ☐
Poor ☐
Moderate ☐
Good ☐
Very Good ☐

84. Does your school have vending machines that serve food?

Yes ☐ No ☐ Unsure ☐

85. **IF YES**, how many vending machines do you have on campus?

____

86. **IF YES**, would you consider that more than half of the foods in the vending machines are healthy?

Yes ☐ No ☐ Unsure ☐

87. Does your school have vending machines that serve drinks?

Yes □ No □ Unsure □

88. **IF YES**, would you consider that more than half of the drinks in the vending machines are healthy?

Yes □ No □ Unsure □

89. In the last 12 months, have any sporting, social or cultural events been sponsored by soft-drinks, fast food or confectionary companies?

Yes □ No □ Unsure □

90. **IF YES**, how many in the last 12 months? ________________

91. In the last 12 months, have any fundraising events been sponsored by soft-drink, fast food or confectionary companies?

Yes □ No □ Unsure □

92. **IF YES**, how many in the last 12 months? ________________

93. Which students are allowed to leave the school grounds during the school day without special permission *(multi-response)*?

Prep □
Year 1 □
Year 2 □
Year 3 □
Year 4 □
Year 5 □
Year 6 □
None □

94. **IF YES**, at what times during the school day are students permitted to leave the school grounds *(multi-response)*?

During lunch □
During morning/ afternoon tea □
Other times □

95. How close is the nearest milk bar or corner store to your school?

Within 100m □
100m to 500m □

500m to 1,000m □
More than 1,000m □
Unsure □

96. How close is the nearest takeaway or fast food outlet to your school (record twice if the milk bar and fast food outlet are the same establishment)?

Within 100m □
100m to 500m □
500m to 1,000m □
More than 1,000m □
Unsure □

97. Are students allowed to drink water in the classroom during class time?

Yes □ No □ Unsure □

98. Are students allowed to eat in the classroom during class time?

Yes □ No □ Unsure □

99. Does your school have a vegetable garden?

Yes □ No □ Unsure □

SECTION F: PHYSICAL ACTIVITY POLICIES

100. Does your school have a written policy (or policies) promoting physical activity?

Yes □ No □ Unsure □

***IF NO, go to Section G**

101. How many policies do you have in place? ________________

Does this policy (or policies) include:

102. Promoting the use of school grounds during 'out of school hours'? Yes □ No □
103. Providing access to sports equipment? Yes □ No □
104. Promoting cycling and walking to school? Yes □ No □

105. Encouraging participation in sports and physical activity? Yes □ No □
106. Ensuring the use of hats for outside play? Yes □ No □
107. Teaching focused on physical activity in the curriculum? Yes □ No □

108. How effective have the policies been on overall promotion of physical activity?

Very Effective □ Moderately Effective □ Not Effective □

109. What proportion of teachers do you think are aware of these healthy eating policies?

All □
Most □
Half □
Very few □
None □

110. Does the school provide copies of your healthy eating and physical activity policies to parents?

Yes □ No □ Unsure □

SECTION G: PHYSICAL ACTIVITY ENVIRONMENT

On average, how many hours a week are devoted to **formal** physical education classes for the following year levels:

111. Year 4 _______ hours ________minutes / per week
112. Year 6 _______ hours ________minutes / per week

On average, how many hours a week are devoted to **organised** sports *(e.g. martial arts, swimming, athletics)* for the following year levels:

113. Year 4 _______ hours ________minutes / per week
114. Year 6 _______ hours ________minutes / per week

115. How adequate is the space for indoor play at your school?

Very Poor □
Poor □
Moderate □
Good □
Very Good □

116. How adequate is the space for outdoor play at your school?

Very Poor ◻
Poor ◻
Moderate ◻
Good ◻
Very Good ◻

117. How adequate is the sporting and active play equipment *(e.g. bats, balls)* at your school?

Very Poor ◻
Poor ◻
Moderate ◻
Good ◻
Very Good ◻

118. Rate the level of priority for physical activity at your school?

Very High ◻
High ◻
Moderate ◻
Low ◻
Very Low ◻

119. Rate the strength of the links that the school has with community sporting and recreation organisations and facilities:

Very High ◻
High ◻
Moderate ◻
Low ◻
Very Low ◻

120. How do you rate the extent to which teachers at your school act as role models by being physically active?

Very High ◻
High ◻
Moderate ◻
Low ◻
Very Low ◻

To what extent, have the following programs or strategies been **implemented** in and around your school?

121. Student pedestrian safety program?

Fully □ Partially □ Not at all □

122. Student cyclist safely program?

Fully □ Partially □ Not at all □

123. Safe houses?

Fully □ Partially □ Not at all □

124. Reducing traffic congestion outside school?

Fully □ Partially □ Not at all □

125. Safer road crossing?

Fully □ Partially □ Not at all □

126. Cycle storage?

Fully □ Partially □ Not at all □

END OF QUESTIONNAIRE

(Thank the participants for their time and valuable input)

Appendix Four:

Copy of accelerometery publication

Open Access Research

BMJ Open

Composition of objectively measured physical activity and sedentary behaviour participation across the school-day, influence of gender and weight status: cross-sectional analyses among disadvantaged Victorian school children

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ABSTRACT

Background: The after-school period has been described as the 'critical window' for physical activity (PA) participation. However, little is known about the importance of this window compared with the before and during-school period among socioeconomically disadvantaged children, and influence of gender and weight status.

Methods: 39 out of 156 (RR=25%) invited primary schools across 26 local government areas in Victoria, Australia, consented to participate with 856 children (RR=36%) participating in the wider study. The analysis sample included 298 Grade 4 and Grade 6 children (mean age: 11.2±1.1; 44% male) whom met minimum accelerometry wear-time criteria and had complete height, weight and health-behaviours questionnaire data. Accelerometry measured duration in daily light-intensity PA (LPA), moderate-to-vigorous PA (MVPA) and sedentary time (ST) was calculated for before-school=8–8:59, during-school=9:00–15:29 and after-school=15:30–18:00. Bivariate and multivariable linear regression analyses were conducted.

Results: During-school represented the greatest accumulation of LPA and MVPA compared with the before and after-school periods. Boys engaged in 102 min/day of LPA (95% CI 98.5 to 104.9) and 62 min/day of MVPA (95% CI 58.9 to 64.7) during-school; girls engaged in 103 min/day of LPA (95% CI 99.7 to 106.5) and 45 min/day of MVPA (95% CI 42.9 to 47.4). Linear regression models indicated that girls with overweight or obesity engaged in significantly less LPA, MVPA and more time in ST during-school.

Conclusions: This study highlights the importance of in-school PA compared with after-school PA among socioeconomically disadvantage children whom may have fewer resources to participate in after-school PA.

Strengths and limitations of this study

- This study has various strengths that centre on the objective examination of the physical activity and sedentary behaviour across the school-day with measured anthropometric indices among disadvantaged primary school children.
- Additionally, this study examines the importance of the before-school, during-school and after-school period for physical activity and sedentary behaviour participation which are commonly examined in isolation, with many studies focusing on the after-school period.
- A limitation of this study is the cross-sectional nature of the data that arises from a subsample of possible participants due to the limited number of accelerometers available to the study team.
- Another limitation is the sampling strategy used which deliberately focused on local government areas with high rates of chronic disease and levels of socioeconomic disadvantage, and thus are not representative of the Victorian population.

INTRODUCTION

Regular physical activity (PA) participation has many documented health benefits for children and adolescents.[1 2] Low levels of PA (termed physical inactivity) among youths have been associated with negative outcomes, including lower high-density lipoprotein cholesterol, hypertension, metabolic syndrome and obesity[4] and increased mental health outcomes (depression, anxiety, self-esteem and cognitive function).[5] Representative self-report

Appendix Five:

Decision-making process: School-level analysis

My primary research question looked at student zBMI in association with the amount that primary schools were doing to promote physical activity (PA) and healthy eating amongst Year 4 and 6 students. The research instrument I used to collect school-level data was the Be Active Eat Well (BAEW) questionnaire, which investigated 33 unique school environmental actions. A list of the 33 questions related to the promotion of healthy eating and PA in primary schools is shown below.

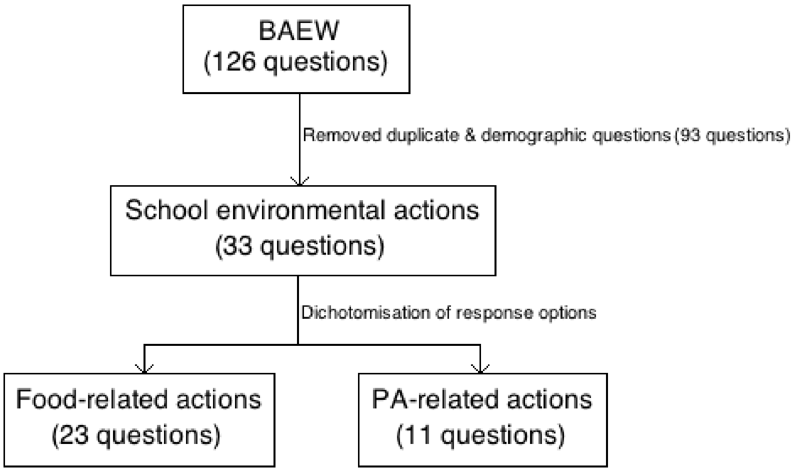
No.	Be Active Eat Well questionnaire items
1	Does your school have a written policy promoting healthy eating?
2	How effective has this policy been on overall healthy eating?
3	Is making a profit an important part of the school foodservice?
4	Does your school have a written policy for types of foods sold by the foodservice?
5	What rating would you give the nutritional value of food sold?
6	What rating would you give for teachers acting as role models for healthy eating?
7	Does your school have a pricing policy to encourage the sale of healthy foods?
8	Does the canteen routinely promote healthy food choices?
9	Is the canteen food menu reviewed on a regular basis?
10	Is fruit available by the school foodservice?
11	Is low-fat milk available by the school foodservice?
12	Is low-fat yoghurt available by the school foodservice?
13	Are filled rolls/ sandwiches available by the school foodservice?
14	Are lollies/ sweets available by the school foodservice?
15	Are hot chips available by the school foodservice?
16	Are energy/ sugary drinks available by the school foodservice?
17	Are crisps available by the school foodservice?
18	Are hot pies available by the school foodservice?
19	Do you have a written policy promoting physical activity?
20	How many hours of formal physical education classes per week?
21	What rating would you give regarding how adequate your indoor play area is?
22	What rating would you give regarding how adequate your outdoor play area is?
23	What rating would you give teachers acting as role models for physical activity?
24	What rating would you give for the quality of available sporting equipment?
25	Does your school have any events sponsored by soft drinks, fast food or confectionary companies?
26	Are students allowed to eat in the classroom?
27	Does your school have a vegetable garden?

No.	Be Active Eat Well questionnaire items (cont.)
28	Does your school provide copies of healthy eating and physical activity policies to parents?
29	To what extent does your school have implemented a policy to reduce local traffic congestion?
30	To what extent does your school have implemented a student pedestrian safety program?
31	To what extent is does your school have implemented a cycling safety program?
32	To what extent does your school have implemented a cycle storage facility?
33	Does your school provide a breakfast service before school?

In line with my primary research question, my hypothesis was that student zBMI would be significantly associated with the number of school-level environmental actions in place to promote healthy eating and PA amongst students. I found such an association amongst females when I looked specifically at the amount that schools were doing to promote healthy eating; i.e. those that did more to promote healthy eating had significantly lower rates of student zBMI.

Despite finding a statistically significant result, I had certainly looked at other ways to strengthen my analysis. Firstly, I had originally planned to approach the model building process using a multi-level model (MLM) to separate the compositional and contextual factors. In anticipation for this, I had completed an MLM training course at Manchester University. The logic behind doing this course was because a well-known rule-of-thumb in MLM is that you need a sample size of at least 30 x 30 (e.g. 30 students x 30 schools) to create a well-fitted model.[62] My data set averaged 22 students across 34 schools; however, the intra-class correlation was zero and it was clear from early on in the model building process that my data were a poor fit for this type of analysis. This was possibly due to having too much variation in the sample size of students between schools. To illustrate, one school in the model would have fifty students, while the next had five. As a result, I approached my data set using a multivariate regression model and this analysis is present in Chapter 7.

Secondly, I had looked closely at Factor Analysis and Principal Component Analysis (PCA) as potential extensions to the data reduction process I had applied to the BAEW questionnaire (the visual representation below shows that the BAEW questionnaire is comprised of 126 questions, but most of these questions were repetitive or irrelevant).



Factor Analysis and PCA can be useful tools to get a small number of variables from a larger set of variables; often used to also create indexes with variables that have similar attributes. Unfortunately, I found a number of issues with these two statistical tests and both proved to be a very poor fit for my school-level data; perhaps for the same reasons as discussed around using MLM. Regardless of this, I doubt that I would have even used the shortened BAEW Score as part of my model building process – I was not entirely comfortable with these statistical tests after I discussed the use of them with two resident biostatisticians at the Nuffield Department of Population Health (NDPH), Oxford University, who regularly provide statistical support to D.Phil. candidates. I was criticised for "cherry picking" at the suggestions of using these two tests on my data set because the primary aim of Factor Analysis / PCA is to reduce the variation in the exposure measure until it finds stronger links with the outcome measure.

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