CHILDHOOD OBESITY IN IRELAND: RECENT TRENDS AND MODIFIABLE DETERMINANTS

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LIST OF ABBREVIATIONS

ABBREVIATION	TERM
BMI	Body mass index
BMR	Basal metabolic rate
BP	Blood pressure
CCLaS	Cork Children's Lifestyle Study
CDC	Center for Disease Control
CI	Confidence interval
CM	Centimetre
CSO	Central Statistics Office
CVD	Cardiovascular disease
DASH	Dietary Approach to Stop Hypertension
DQI	Diet quality indices
DQS	Diet quality score
ENERGY	European energy balance research to prevent excessive weight gain among youth
FFQ	Food frequency questionnaire
G	Grams
GUI	Growing Up in Ireland
HEI	Health eating index
IOTF	International obesity taskforce
IQR	Inter quartile range
KCAL	Kilocalories
KG	Kilogram
KIDMED	Mediterranean diet quality index for children and adolescents
LSAC	The Longitudinal Study of Australian Children
METS	Metabolic equivalents
MI	Multiple imputation
MM	Millimetre
MVPA	Moderate to vigorous activity
NHANES	National Health and Nutrition Survey
OR	Odds ratio
PAF	Population attributable fractions
PPS	Probability proportionate to size
RAPID	Revitalising areas by planning investment and development
RC-DQI	Revised children's diet quality index
RR	Relative risk
SD	Standard deviation
SSB	Sugar sweetened beverage
SES	Socio-economic status
SOP	Standard operating procedures
TST	Total screen time
TV	Television
UK	United Kingdom
USA	United States of America
WHO	World Health Organisation

DECLARATION

I declare that this thesis has not been submitted for another degree at this or at any other University. The work, upon which this thesis is based, was carried out in collaboration with a team of researchers and supervisors who are duly acknowledged in the text of the thesis. The Library may lend or copy this thesis upon request.

Signed: ______________________________ Date: ______________________

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THESIS ABSTRACT

Background

Childhood obesity is a global epidemic posing a significant threat to the health and wellbeing of children. To reverse this epidemic, it is essential that we gain a deeper understanding of the complex array of driving factors at an individual, family and wider ecological level. Using a social-ecological framework, this thesis investigates the direction, magnitude and contribution of risk factors for childhood overweight and obesity at multiple levels of influence, with a particular focus on diet and physical activity.

Methods

A systematic review was conducted to describe recent trends (from 2002-2012) in childhood overweight and obesity prevalence in Irish school children from the Republic of Ireland. Two datasets (Cork Children's Lifestyle [CCLaS] Study and the Growing Up in Ireland [GUI] Study) were used to explore determinants of childhood overweight and obesity. Individual lifestyle factors examined were diet, physical activity and sedentary behaviour. The determinants of physical activity were also explored. Family factors examined were parental weight status and household socio-economic status. The impact of food access in the local area on diet quality and body mass index (BMI) was investigated as an environmental level risk factor.

Results

Between 2002 and 2012, the prevalence of childhood overweight and obesity in Ireland remained stable. There was some evidence to suggest that childhood obesity rates may have decreased slightly though one in four Irish children remained either overweight or obese.

In the CCLaS study, overweight and obese children consumed more unhealthy foods than normal weight children. A diet quality score was constructed based on a previously validated adult diet score. Each one unit increase in diet quality was significantly associated with a decreased risk of childhood overweight and obesity.

Individual level factors (including gender, being a member of a sports team, weight status) were more strongly associated with physical activity levels than family or environmental factors. Overweight and obese children were more sedentary and less active than normal weight children. There was a dose response relationship between time spent at moderate to vigorous physical activity (MVPA) and the risk of childhood obesity independent of sedentary time. In contrast, total sedentary time was not associated with the risk of childhood obesity independent of MVPA though screen time was associated with childhood overweight and obesity.

In the GUI Study, only one in five children had 2 normal weight parents (or one normal weight parent in the case of single parent families). Having overweight and obese parents was a significant risk factor for overweight and obesity regardless of socio-economic characteristics of the household. Family income was not associated with the odds of childhood obesity but social class and parental education were important risk factors for childhood obesity. Access to food stores in the local environment did not impact dietary quality or the BMI of Irish children. However, there was some evidence to suggest that the economic resources of the family influenced diet and BMI.

Discussion

Though childhood overweight and obesity rates appear to have stabilised over the previous decade, prevalence rates are unacceptably high. As expected, overweight and obesity were associated with a high energy intake and poor dietary quality. The findings also highlight strong associations between physical inactivity and the risk of overweight and obesity, with effect sizes greater than what have been typically found in adults. Important family level determinants of childhood overweight and obesity were also identified. The findings highlight the need for a multifaceted approach, targeting a range of modifiable determinants to tackle the problem. In particular, policies and interventions at the shared family environment or community level may be an effective mean of tackling this current epidemic.

1. INTRODUCTION

1.1. Introduction

The World Health Organisation (WHO) has described obesity as one of the most significant public health challenges of the 21st century [1]. In children, the worldwide prevalence of obesity has increased significantly over the final three decades of the 20th century [2]. This poses a significant threat to public health as obesity is associated with a number of short and long term health consequences along with wider social and economic costs [3]. Obesity is defined as an excessive or abnormal fat accumulation which poses a risk to health [1]. Measuring and defining obesity during childhood is associated with a number of challenges, though body mass index (BMI) [weight/height^2] is commonly used to define childhood overweight and obesity in a research setting [4].

Obesity is intertwined with diet and physical activity [5] and in simple terms is described as a persistent positive energy balance where energy intake is greater than energy output [6]. However, obesity is a complex problem and its aetiology is multifaceted with a number of known risk factors [7]. Childhood obesity can occur as a result of a child's biology (genetic pre-disposition and/or metabolism), lifestyle choices and external influences including the home and local environment [8-12]. As risk factors for childhood obesity can interact, lifestyle choices can be influenced by the 'obesogenic' environment which encourages excessive energy intake and low levels of physical activity [13].

To date, few studies have collected in-depth data on a broad range of multilevel risk factors for childhood obesity, especially in Ireland. In addition, risk factors for childhood overweight and obesity have traditionally been poorly measured, in particular, diet and physical activity, variables which are complex and are measured with large amounts of error. As a result, the importance and contribution of risk factors for childhood obesity remain poorly understood [14].

1.2. Aim

To describe recent trends and explore determinants of childhood overweight and obesity in Ireland

1.3. Objectives

This thesis has 7 objectives:

1. To systematically collate and describe overweight and obesity prevalence data from primary school aged children in the Republic of Ireland between 2002 and 2012
2. To describe the design and conduct of a cross-sectional survey which collected data on the prevalence and multilevel influences of childhood overweight and obesity in Ireland
3. To examine the association between dietary quality (defined using a modified adult diet score) and the risk of childhood overweight and obesity

4. To investigate the multilevel effects of individual, family and environmental factors on physical activity levels in children

5. To investigate the independent association of objectively measured moderate to vigorous physical activity (MVPA) and sedentary behaviour on the risk of childhood overweight and obesity

6. To explore the association between parental weight, characteristics of the socio-economic status (SES) of the household and the odds of childhood overweight and obesity

7i. To construct a diet quality score (DQS) from a brief dietary assessment tool used in the Growing Up in Ireland (GUI) Study (to be utilised in objective 7ii) and to examine the association between diet quality and the odds of childhood overweight and obesity.

7ii. To explore the impact of the local food environment (measured as the distance to and density of food outlets in the local area) on diet quality and BMI in children

1.4. Research setting

Two data sources are used to describe determinants of childhood overweight and obesity: the Cork Children's Lifestyle (CCLaS) Study and the GUI Study. I was the lead researcher of the CCLaS Study and was involved in the design, conduct and analysis of the study. Piloting and data collection for the study took place in Cork in 2012/2013. Over 1,000 eight to eleven year old school children took part in the study. The CCLaS Study was funded by the National Children's Research Centre, Crumlin, Dublin. I conducted secondary analysis of the GUI Study. The GUI Study is a nationally representative sample of 8,568 nine year olds and wave one of data collection was undertaken in 2007/2008. The GUI Study was funded by the Government of Ireland through the Department of Children and Youth Affairs in association with the Department of Social Protection and the Central Statistics Office.

1.5. Thesis outline

This thesis is comprised of 7 papers which describe recent trends and determinants of childhood overweight and obesity in Irish school children. Figure 1 illustrates the aim, objectives and papers included in this thesis. Chapter 2 provides a brief introduction to the extent of the problem of childhood overweight and obesity.

A systematic review was undertaken and describes trends in childhood overweight and obesity prevalence in the Republic of Ireland between 2002 and 2012 (Chapter 3). This data had not been systematically collated prior to this thesis being undertaken.

Chapter 4 describes the design, piloting and conduct of the CCLaS Study while the methods used in the GUI Study are reported in Chapters 6, 8 and 9.

Individual, family and environmental level determinants of childhood overweight and obesity are conceptualised using a social-ecological framework (see Chapter 2) and explored in Chapters 5 to 9. Individual lifestyle factors assessed are diet, physical activity and sedentary behaviour. A dietary quality score (DQS) was constructed (kidDASH score) and is presented in Chapter 5. Our DQS (the kidDASH score) is a modified version of the Dietary Approach to Stop Hypertension (DASH) score which is associated with obesity in adults [15]. Chapter 5 explores the association between kidDASH and childhood overweight and obesity.

Chapter 6 investigates individual, family and environmental level factors associated with physical activity levels in children. Chapter 7 describes levels and patterns of physical activity in school aged children. Furthermore, Chapter 7 investigates the independent association of objectively measured MVPA and sedentary behaviour on the risk of childhood overweight and obesity.

Family level factors are examined in Chapter 8. The association between parental weight status, family level SES and the odds of childhood overweight and obesity are examined. Parent weight is assessed separately for mothers, fathers and using a combined single index variable. Three measures of family level SES are explored: parent education, social class and household income.

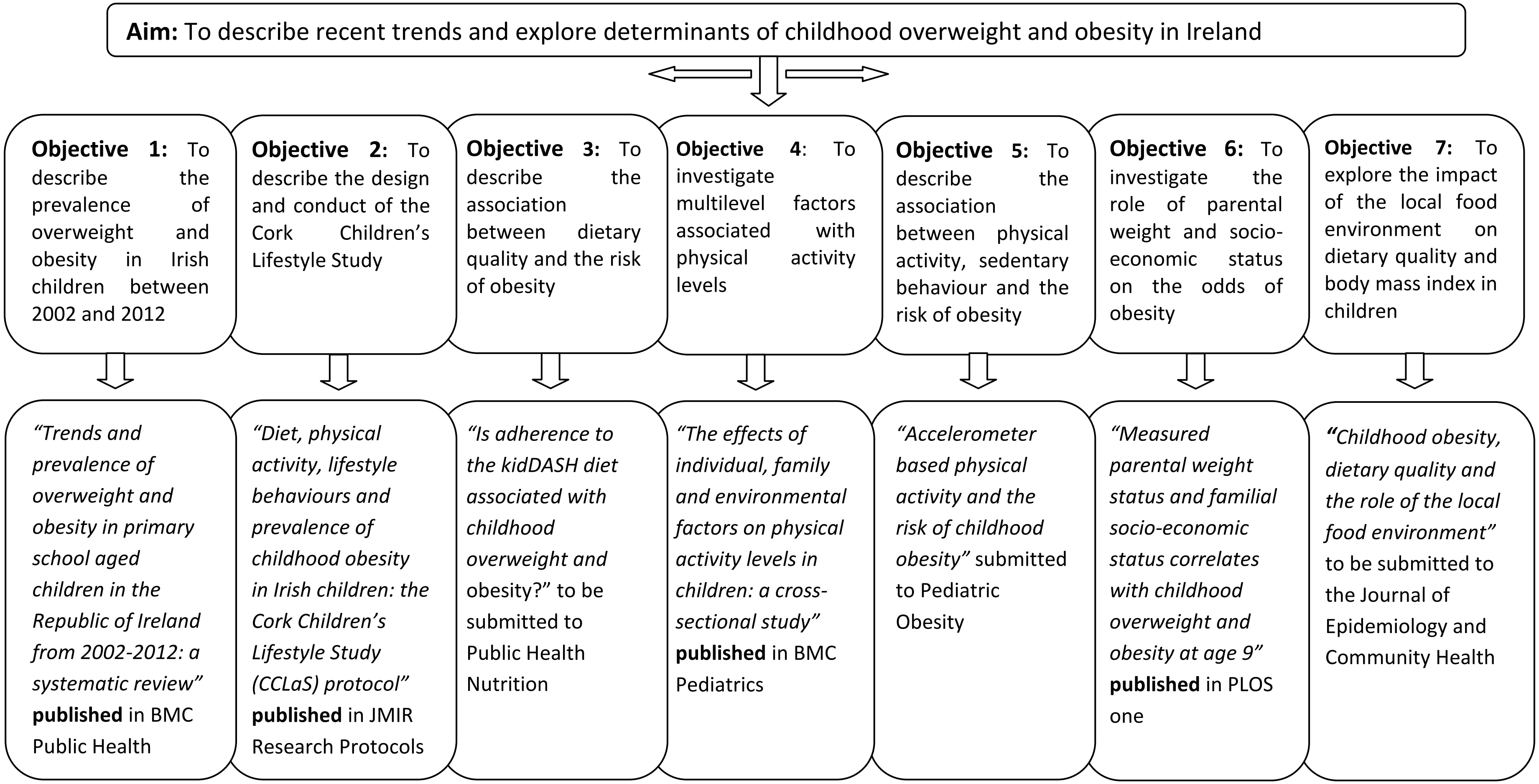
The impact of food access in the local environment on diet quality (see Appendix 4 for information on the construct of the DQS) and BMI in children is described as an environmental level risk factor in Chapter 9. This chapter builds upon a previous study which explored the association between diet and the local food environment in Irish adults.

Chapter 10 provides an overall discussion of the main findings, the strengths and limitations of this thesis and makes some suggestions for future research.

1.6. Author's contribution

I was the lead author of the research papers in Chapters 3, 4, 7, 8 and 9. This involved the formulation of the research question for each chapter, conducting literature searching, data analysis and drafting of each manuscript. I was the lead researcher of the CCLaS Study and was involved in all aspects of the study. Ms Catherine Perry, a research assistant on the CCLaS Study in the Department of Epidemiology and Public Health, UCC, who I have worked closely with over the last 4 years, conducted the statistical analysis for the manuscript in Chapter 5. I was involved in the formulation of the research question and co-wrote the manuscript. I also provided advice on the analysis plan. Ms Sharon Cadogan, a PhD student in the Department of Epidemiology and Public Health, UCC conducted the analysis in Chapter 6. I was involved in the formulation of the research question and provided statistical advice. I was also involved in drafting the manuscript. This chapter builds upon Sharon's Master's thesis and I acted as Sharon's tutor for her thesis.

Figure 1. Overview of thesis including aims and objectives



Footnote: Details on the construct of the DQS used for objective 7 is described in Appendix 4

2. BACKGROUND

This chapter provides a brief overview of childhood overweight and obesity. This chapter describes BMI as a method to define childhood overweight and obesity. Secondly, the extent of the problem globally is described. Thirdly, the short and long term health consequences and the wider economic costs of obesity are outlined. Fourthly, approaches to conceptualising and assessing risk factors for childhood overweight and obesity are described. Finally, risk factors for childhood overweight and obesity are described using a three tiered (individual, family and environmental level factors) social-ecological framework.

2.1. Defining childhood overweight and obesity using body mass index (BMI)

2.1.1. Overview of indicators for childhood overweight and obesity

Childhood adiposity can be assessed using a number of methods. Highly accurate methods to estimate adiposity include underwater weighing, total body water, energy X-ray absorptiometry and total body electrical conductivity. However, these methods are not generally feasible in an epidemiological or public health research setting due to their high cost and complexity [16, 17]. In a research setting, BMI, waist circumference, skinfold thickness and bioelectrical impedance measurements are more frequently used indicators of child weight status. Currently, there is no consensus on thresholds for defining overweight and obesity in children using waist circumference, skinfold thickness or bioelectrical impedance measurements. BMI arguably remains the most commonly used and most well defined indicator of childhood obesity [4]. Therefore, childhood obesity is defined using BMI in this thesis.

2.1.2. What is BMI?

Height and weight measurements are used to calculate BMI. BMI is calculated by dividing a person's weight in kilograms by the square of their height in metres (kg/m^2) [1]. BMI is a valid, non-invasive, reproducible, inexpensive and convenient method of determining childhood obesity [4]. Children are typically familiar with height and weight measurements which can make BMI easier to measure than other anthropometric measures in a research setting. A disadvantage of BMI is that it does not give any indication of body fat distribution nor does it distinguish fat mass from fat free mass [18, 19]. Objectively measured height and weight measures are preferential to self-reported measures. Numerous studies have suggested that parent and self-reported measures tend to overestimate height and underestimate weight [20-22].

2.1.3. BMI measurement issues in a research setting

A number of measurement issues need to be considered when measuring BMI in a research setting. Appropriate choice of equipment, regular re-training and standard procedures are all necessary to achieve accurate, valid measurements, with little error. Height and body composition constantly change during childhood and this needs to be accounted for when defining child weight status [1]. Child stature and body composition can also vary on a daily basis. For example, hydration status, contents of gastro-intestinal and bladder, diurnal hormonal fluctuations, fatigue and alterations in position can all influence measurements [4]. Using a standard operating procedure (SOP) can help account for some of these daily variations in a research setting and can also reduce measurement error.

Measurement error can occur when taking height and weight measurements in a research setting. Random measurement error can impact on the precision of height and weight readings by adding to the variability of the true result. When error in measurements occurs randomly in a study, average readings will remain relatively unaffected. Systematic measurement error can also occur during measurements and can influence the validity of height and weight measurements. For example, one researcher may systematically take higher or lower measures than the actual true value. This can also lead to the misclassification of weight status and can lead to differentials in results between observers. Observer variations in measurements can be combated by having as few individuals as possible taking measurements and by taking more than one of each measurement and using the mean of the readings for analysis [4, 23].

2.1.4. Defining overweight and obesity using BMI

BMI can either be analysed as a continuous variable or it can be categorised to define weight status. There is a lack of consensus regarding standards for defining childhood obesity using BMI in the Republic of Ireland [24]. A number of national and international reference data values or growth charts are available for defining overweight and obesity in children. However, different reference values produce different estimates [25]. Thus, careful consideration is needed when defining overweight and obesity. Examples of reference values include the United Kingdom (UK) and United States of America (USA) national reference charts for BMI [26]. WHO reference data are commonly used to assess healthy growth in developing countries [4]. The age and sex specific International Obesity Taskforce (IOTF) cut off points are widely used globally [27] and have been recommended for use in research [28]. Thus, the IOTF cut off points are used to define overweight and obesity in this thesis.

IOTF cut off points were published in 2000 and were developed using height and weight data from six countries (Brazil, USA, Hong Kong, Singapore, Great Britain and the Netherlands) [27]. These cut offs points were designed to correspond to the statistical distribution of adult overweight (>25kg/m^2 to <30kg/m^2) and obesity (≥30kg/m^2). The IOTF cut off points have high specificity but has low sensitivity [29]. Originally, the IOTF definitions were designed to assign children to a category of either underweight, normal weight, overweight or obese [27]. More recently, these cut-off points have been extended and allow BMI to be expressed as centile scores [30].

2.2. Global trends and prevalence of childhood overweight and obesity

Global estimates suggest that 170 million children worldwide are either overweight or obese [31]. A study which examined trends and prevalence of childhood overweight and obesity in over 60 countries globally between 1980 and 2005 found that childhood obesity was a growing problem in all developed countries and in some developing countries [2]. However, more recent literature suggests that childhood obesity prevalence rates may be beginning to stabilise in developed countries (see Chapter 3) [32].

Data from Europe and the USA are described below to place Irish prevalence rates in an international context. Chapter 3 will describe overweight and obesity trends in primary school aged children in the Republic of Ireland.

2.2.1 Prevalence and trends in Europe

Jackson-Leach and Lobstein, 2006 [33] presented data on the rate of change in the prevalence of child and adolescent overweight (including obesity) in European children aged 5 to 17.9 years. The study found that the prevalence of overweight increased by 0.5 percentage points annually in the 1980s and by 1.0 percentage point annually during the 1990's. Lobstein and Frelut, 2003 [34] summarised data from 20 surveys which had objective height and weight data from pre-pubertal children between 1992 and 2001. Using IOTF definitions, the prevalence of overweight and obesity ranged from 12-36%. Genetic predisposition and the 'obesogenic' environment were suggested as possible factors for the varying prevalence rates between countries. The authors observed lower overweight and obesity prevalence rates in central and eastern European countries. Higher prevalence rates were found in Southern European countries. Poor economic growth, recession and political factors were suggested as possible explanations for the lower prevalence rates in central and eastern European countries.

As objective height and weight data in European children was scarce and monitoring systems inadequate, the WHO implemented the European Childhood Obesity Surveillance Initiative in 13 European countries (including Ireland) in 2007. The first wave of the initiative was undertaken in 2007/2008 in children aged 6 to 9 years. Wijnhoven et al, 2012 [35] reported that the prevalence of overweight and obesity varied by country from 11-37% in boys and from 15-35% in girls using IOTF definitions. Higher prevalence rates were observed in Mediterranean countries (eg. Italy, Portugal) when compared with Northern (eg. Norway, Sweden) and Eastern countries (eg. Bulgaria, Czech Republic).

The second wave of data collection took place in 2009/2010 in 15 countries. Changes in the prevalence of overweight and obesity among the 9 countries which participated in previous wave of data collection varied significantly [36]. Countries reported either an increase, decrease or no change in absolute mean BMI ranging from -0.4kg/m^2 in Portugal and Italy to +0.3kg/m^2 in Norway. The third wave of data collection took place in the school year 2012/2013, though findings comparing rates between countries remain unpublished to date.

2.2.2. Prevalence and trends in the United States of America (USA)

Estimates from the USA suggest that since 1980, the prevalence of obesity has tripled in children aged 2 to 5 years and prevalence rates have quadrupled in children aged 6 to 11 years [37]. The National Health and Nutrition Survey (NHANES) is an ongoing panel survey which collects objective height and weight data from nationally representative samples of children in the USA. In 1999/2002, 31% of children were overweight and 16% were obese according to US definitions [38]. In 2003/2004, 33.6% of children were overweight and 17.1% obese. Ogden et al, 2006 [39] reported a significant increasing trend in the prevalence of childhood obesity between 1999 and 2004. In NHANES 2007/2008, prevalence rates appeared to be stabilising with 32% of children overweight and 16.9% obese [40]. Ogden et al, 2012 [41] reported that the prevalence of overweight and obesity in NHANES 2009/2010 were 31.8% and 16.9% respectively and prevalence rates have remained stable in NHANES 2011/2012 [42].

Skinner et al, 2014 have suggested that though the prevalence of childhood obesity may be stabilising in the USA, rates of severe obesity are continuing to increase especially in non-Hispanic black boys and Hispanic girls [43]. Limited data are available on the incidence of obesity [44]. Cunningham et al, 2014 evaluated data measured at 7 time points (from 1998-2007, mean age 5.6 years at baseline) during the Early Childhood Longitudinal Study which was conducted in the USA. The authors reported that incident obesity is more likely to occur at a young age. Young children who were overweight at age 5 were more likely to become obese compared to their normal weight counterparts [44].

2.3. Consequences of childhood overweight and obesity

Childhood obesity is associated with a number of short and long term consequences including physical and psychological health problems [45, 46]. These include metabolic complications, type 2 diabetes, musculoskeletal disorders, respiratory problems, risk factors for cardiovascular disease (CVD) and low self-esteem [47-52]. Obesity also has wider economic consequences including health care costs [53].

2.3.1. Wellbeing and social consequences

Obesity is associated with wellbeing and can impact self-esteem and social functioning [5]. Reilly et al, 2003 [54] reported that obese children had a greater risk of psychiatric and psychological problems including behavioural problems and low self-esteem when compared to non-obese children. A longitudinal study by Strauss, 2000 found that obese children with decreasing self-esteem over time demonstrated high rates of loneliness and nervousness [55].

Social stigma is associated with overweight and obesity [5]. Griffiths et al, 2011 conducted a systematic review and reported findings on the association between self-esteem, quality of life and childhood obesity. The authors reported that there was strong evidence to suggest that there is an association between quality of life and childhood obesity. Obese children had lower self-esteem in terms of physical competence (athletic competence) and physical appearance when compared to their non-obese peers [52]. The consequences of being obese can also have a negative impact on daily activities [5]. For example, some evidence suggests that obesity during childhood is associated with reduced school performance. Furthermore, obese children are more likely to obtain lower educational attainment and secure lower income jobs in the future when compared to non-obese children [54].

2.3.2 Short term physical health consequences

Childhood obesity has a number of short term health consequences. Must and Strauss, 1999 [45] reviewed literature on CVD risk factors and childhood obesity. The review suggested that obese children had an increased risk of elevated blood pressure (BP), high cholesterol and triglycerides when compared to non-obese children. A prospective study by Lawlor et al, [56] also reported that increased adiposity during childhood was associated with risk factors for CVD including high systolic BP. Smith et al, 2014 reported an association between musculoskeletal pain and childhood overweight and obesity [57]. Evidence from prospective studies suggests that there is a significant association between childhood obesity and asthma incidence [58].

2.3.3. Long term physical health consequences

Childhood obesity has long term consequences for health [59]. A systematic review by Reilly and Kelly, 2010 reported that overweight or obesity during childhood and adolescence was associated with premature mortality in adulthood [60]. Recent evidence suggests that children born at the beginning of the 21st century in market economies may have a shorter life expectancy than that of their parents due to the negative health effects of obesity [26]. As obesity can track throughout the life-course, up to 50% of obese children will become obese adults [61]. Some co-morbidities associated with childhood obesity may also persist into adulthood [45, 62]. For example, Reilly and Kelly, 2010 reported that overweight or obesity during childhood and adolescence was associated with an increased risk of cardiometabolic morbidity and asthma in adulthood [60].

2.3.4. Economic consequences

Obesity is associated with direct and indirect costs at a societal level. Direct costs include medical costs while indirect costs include job absenteeism [63]. The cost of obesity has become increasingly researched in adult populations over recent years and different studies have used different approaches [53]. The cost of childhood obesity is understudied and the majority of the evidence relates to adult obesity.

In the USA, the annual direct cost of childhood and adolescent obesity including outpatient costs, accident and emergency visits, and prescription costs is estimated to be 14.1 billion dollars per annum [64] and inpatient costs have been estimated to be 237.6 million dollars per annum [65]. The cost of obesity is greater when an obese child becomes an obese adult [63]. In the USA, medical spending associated with obesity was estimated to be as high as 147 billion in 2008 [66]. Furthermore, Wang et al, 2008 [67] projected the potential burden of overweight and obesity in the USA based on overweight and obesity data from NHANES between the 1970s and 2004. The authors suggested that by 2030, between 861 to 957 billion dollars of healthcare spending could be attributed to overweight and obesity accounting for 16% to 18% of total healthcare costs.

To date, the cost of childhood obesity in Ireland has not been calculated. In 2009, the direct and indirect cost associated with adult obesity in the Republic of Ireland was estimated to be €1.13 billon [68]. Of this, 35% was direct healthcare spending (eg. hospital visits, drugs) and 65% was indirect healthcare costs (eg. absenteeism, premature mortality). This direct healthcare spending in 2009 equated to 2.7% of total healthcare costs [68]. The authors estimated that the direct healthcare costs associated with obesity could increase to €5.4 billion by 2030 [69].

2.4. Approaches to conceptualise and assess risk factors for childhood overweight and obesity

Our understanding of risk factors associated with childhood overweight and obesity has improved over time [70]. Some earlier research had a very simple approach to describing obesity [71, 72] whereas more recent frameworks have become increasingly complex [7]. Some earlier research focussed on energy imbalance as the root of the problem where poor diet and physical inactivity were described as the most predominant risk factors for obesity [73, 74]. This simple approach to understanding childhood obesity has not brought us closer to understanding how to reverse the obesity epidemic [70], though diet and physical activity remain as central risk factors for obesity.

Rapid increases in obesity prevalence between the 1970 and the late 1990s suggest that lifestyle choices along with wider environmental factors are important drivers of the current high prevalence of obesity [75-79]. The term the ‘obesogenic’ environment has been coined to describe our environment where food is readily available and sedentary behaviours are common [79]. Factors such as increasing urbanization, transportation and technology have been described as factors associated with the ‘obesogenic’ environment [80]. This suggests that we need to adopt a wider approach to understand the context in which obesity related behaviours including, diet and physical activity occur. Understanding factors which are associated with diet, physical inactivity and obesity at multiple levels of influence will allow us gain a deeper understanding of the problem [70, 75-79, 81]. Thus, conceptual models which describe the wide and complex range of factors associated with childhood obesity need to be utilised.

The foresight map is a more recent framework designed to illustrate the complex set of factors associated with obesity. Energy imbalance is at the centre of the foresight map, and risk factors for obesity are intertwined in a complex web. The foresight map was developed by a multidisciplinary group in the UK and describes the diverse and complex range of factors associated with obesity. This model includes over 100 risk factors which are interconnected and can directly or indirectly impact on obesity risk [7].

Social-ecological theory has been described as a particularly promising tool for understanding childhood obesity [82] and is used in this thesis. As diet and physical activity remain at the core of the problem, this thesis will place a strong focus on these variables. The social-ecological framework conceptualised for this thesis is described below.

2.4.1. Social-ecological framework

Social-ecological framework serves as a useful means of conceptualising and understanding the complex, multilevel set of factors associated with childhood obesity. Social-ecological theory recognises that understanding the determinants of childhood obesity is complicated by the complex interaction between individual lifestyle choices with wider family and environmental factors which provide the context in which children live [82].

Bronfenbrenner, 1979 proposed one of the earlier social-ecological theories called the systems theory. This theory suggests that there are three levels of environmental influences which can impact on health related behaviour. These are the Microsystem (the interaction of family members), the Mesosystem (the physical family or school) and the Exosystem (larger social systems of culture, economics and politics) [83]. A second theory called social ecology was developed by Moos and suggests that environmental level factors can be placed in one of four categories. These categories are physical settings (the built environment), organizational settings (schools), the ‘human aggregate’ (the socioeconomic characteristics of children/families) and the ‘social climate’ (the supportiveness of a social setting for a particular behaviour) [83].

More recent social-ecological models have been proposed or discussed by Davison and Birch, 2001 [84], Story et al, 2008 [85] and Lytle, 2009 [82]. All these authors suggest that health related behaviours are influenced at multiple levels ranging from individual level choices to wider environmental influences. In particular, the framework defined by Davison and Birch, 2001 [84] is a useful means of conceptualising the complex set of individual, family and environmental levels factors which are associated with weight status.

Based on the data available for this thesis, a 3 tiered social-ecological framework is used to conceptualise and describe factors which can contribute to the risk of obesity. In particular, the conceptual framework for this thesis will draw upon the work proposed by Davison and Birch, 2001. Risk factors for childhood overweight and obesity will be described using 3 broad headings: individual factors, family factors and community level environmental factors. In this thesis, diet, physical activity and sedentary behaviours are described as individual level factors. Parental weight and SES of the household are described as family level factors which reflect the shared family environment. The local food environment is described as an environmental factor which is associated with diet and the risk of obesity. Each of these risk factors is described below.

2.5. Individual level factors for childhood overweight and obesity

A wide range of individual level factors are associated with an increased risk of childhood overweight and obesity. Genetic predisposition, metabolic problems and ethnic origin can put some children at an increased risk of obesity [86]. Children of black, south Asian, Hispanic and native American origin have an increase risk of obesity when compared to white children [87]. This may reflect cultural and social factors and may also interact with genetics factors. However, as the focus of this thesis is on modifiable lifestyle factors, the section below describes diet, physical activity and sedentary behaviour. The measurement, categorisation and association of each risk factor with overweight and obesity are discussed.

2.6. Diet

Diet plays a key role in maintaining good health and wellbeing. The 'nutrition transition' is the term used to describe changes in dietary intake which have coincided with economic growth and globalisation in recent decades. This includes increasing consumption of sugar, animal fats and fast foods [88, 89]. Traditionally the association between poor diet and obesity has been assessed at an individual food, food group or nutrient level [90]. However, more recent approaches to assessing diet involve using a whole diet approach [90-92].

2.6.1. Overview of dietary assessment

Diet is difficult to measure accurately, especially in large scale epidemiological studies. Nutrition assessment can be conducted at a group or an individual level. Food balance sheets and household budget surveys can be used to estimate food intake at a group or population level. Individual methods of assessing food and dietary intake are preferable when estimating energy and nutrient intake within a predefined population [93].

Three commonly used methods of assessing individual level dietary assessment are food frequency questionnaires (FFQ), dietary recalls and food records/diaries (which can be estimated or weighed). Questionnaire data on key dietary indicators can also be used to collect dietary data. Individual level dietary assessment tools can capture a number of aspects of diet including the types of foods/drink consumed, portion sizes, the eating occasion (eg. breakfast, snack) or the eating location (eg. home, school, car). A number of practical measurement issues are associated with all dietary assessment tools and need to be accounted for and acknowledged when interpreting data.

Problems associated with dietary assessment include bias and inaccurate reporting. Due to intra-individual variation, several days of monitoring are needed to produce a representative overview of habitual intake. Recall bias may occur where foods that are consumed more recently are recalled more accurately than those consumed at an earlier time point. Under or over reporting may occur as a result of social desirability and social approval bias. For example, healthier foods may be over reported while unhealthy foods may be underreported or excluded from dietary records. Under reporting is more common than over reporting, especially in obese participants. Some children have problems estimating portion size which can influence estimation of nutrient and energy intake [93-96].

Child age can influence cognition, food habits and ability to report portion size. Children from the age of 9 have been found capable of self-reporting dietary intake. Younger children tend have more structured food habits than older children which may aid recall. Cognition can impact literacy, attention span, concept of time, familiarity with food types, packaging and cooking methods. Age, gender, cognition and weight status can also impact on the honesty of reporting. Finally, dietary intake relies heavily on the use of food tables and this can also introduce error into dietary data analysis. For example, food tables typically contain a limited number of foods [93-96].

2.6.2. Individual foods and childhood obesity

A number of individual foods and food groups are associated with overweight and obesity [97, 98]. For example, some studies have found an inverse association between fruit and vegetable intake and the risk of obesity though the evidence base remains inconclusive [99-102]. Higher consumption of whole grains has been found to be associated with a reduced risk of obesity though whole grain intake is typically low in children [100, 103].

Ultra-processed and convenience foods high in fat, sugar and salt have become synonymous with the modern obesogenic environment. Junk food and sugar sweetened beverage (SSB) consumption in children has increased over the last two decades [104, 105]. Bowman et al, 2004 [106] found that on days where children consumed fast food products, energy intake was higher and fruit and vegetables consumption was lower when compared to days where fast food products were not consumed. Ludwig et al, 2001 found that for each additional serving of SSBs, the odds of becoming overweight increased by sixty percent in 11 and 12 year old children [107]. Grimes also reported that SSB consumption was associated with obesity risk and that there is an association between salt intake and SSB intake [108]. However, inconsistencies in findings between individual foods and obesity may suggest that there are limitations to describing the association between diet and complex diseases such as obesity when only assessing one food [91]. Thus, assessing individual foods may not provide an appropriate overview of overall diet due to complex synergies between foods and/or nutrients [109, 110].

2.6.3. Overall diet and childhood obesity

Recently, overall approaches to diet have become more commonly used in nutritional epidemiology [92]. The concept of overall diet is gaining considerable attention as it is now recognised that people eat combinations of foods rather than individual foods or nutrients. Furthermore, combinations of foods are eaten in particular settings and in different contexts can also reflect social, environmental and cultural dimensions of diet [111].

There are two main approaches to assessing overall diet, an a-priori or a-posteriori approach. An a-posteriori approach is a data driven method which derives patterns using statistical methods based on the dietary data being analysed. Using interrelationships, large numbers of dietary variables can be collapsed into fewer variables. Two widely used methods are factor analysis and principle component analysis. Alternatively, using a clustering statistical approach, mutually exclusive groups of individuals with similar dietary patterns can be derived [112]. This is known as latent class analysis.

An a-priori approach involves quantifying dietary quality using a DQS or diet quality indices (DQI). DQS aim to examine the overall diet and typically compare diet as a whole to current dietary recommendations or guidelines. An a-priori approach to diet may be particularly useful in terms of translating evidence on healthy eating patterns to the public. A large number and diversity of indices have been designed and can be classified as a function of their method as (1) indices based on intakes of nutrients, (2) indices based on the consumption of specific foods or food groups or (3) indices that combine both approaches [113].

To date, most of these DQS have been developed and used in adult populations. Few DQS have been developed to assess diet quality in children [92]. Some DQS for children have been adapted from adult scores and validated scores for children include the Mediterranean Diet Quality Index for Children and Adolescents (KIDMED) which was adapted from the Mediterranean Diet adherence score, the Youth Healthy Eating Index which was modified from the Healthy Eating Index (HEI) and the Revised Children's Diet Quality Index (RC-DQI). Each of these indices evaluates dietary patterns which may be protective against obesity during childhood.

Limited research is available on the association between DQS and childhood obesity [92]. Where associations between childhood obesity and DQS have been examined, moderate associations between DQS and childhood overweight and obesity were observed [114-117]. Jennings et al, 2011 completed a study of 9-10 year old British children which collected dietary data and adapted 3 diet scores (Mediterranean Diet Score, Healthy Diet Indicator and the Diet Quality Index score) to reflect the diet of children. The Healthy Diet Indicator and the Diet Quality Index score were both associated with childhood obesity after adjusting for potential confounders including physical activity levels and total energy intake. The Mediterranean Diet was not strongly associated with childhood obesity in this study [114]. A study from Cyprus found a significant association between diet quality assessed using the KIDMED score and weight status though the association did not remain significant when physical activity was added to the regression model [116]. Perry et al, (unpublished) devised a DQS based on Irish healthy eating guidelines from a short 20 question FFQ and found a moderate association between childhood obesity but not overweight in Irish 9 year old children. This paper of which I am a co-author is discussed in Appendix 4.

2.7. Physical activity

The WHO defines physical activity as "any bodily movement produced by skeletal muscles that requires energy expenditure" [118]. Engaging in regular physical activity is essential for normal growth and development [119, 120] and has several health benefits including maintaining a healthy weight [121]. The WHO recommends that children engage in 60 minutes of MVPA daily and that increasing physical activity levels beyond this has greater benefits for health [118, 122].

2.7.1. Overview of physical activity assessment

Accurately assessing and quantifying physical activity in free living children is difficult as physical activity does not have a precise biological marker. Physical activity measurement tools can describe the frequency, intensity and/or distribution of activity in a defined population. Assessment tools may also assess the domain of physical activity. For example, children can perform physical activity in school, at home or for transportation and this data can be captured using some physical activity assessment tools [119]. A number of measurement units are available to describe physical activity. These include metabolic equivalents (METS), energy expenditure over a defined period (eg. kcals/day) or minutes spent at light, moderate and vigorous physical activity [119]. Levels of physical activity (eg. moderate, vigorous) can be described based on the intensity at which an activity is performed compared to the intensity of rest [118].

Currently, there is no consensus on a “gold standard” method for assessing physical activity in free living conditions. Some more common methods of assessing free living physical activity include self-reported questionnaires, instrumental movement devices and direct observation [123]. Self-reported measurement tools include questionnaires, physical activity diaries and previous day physical activity recalls. Self-reported tools are susceptible to recall bias and social desirability bias [119]. Baranowski, 1984 also suggested that children under 10 years may not be able to accurately recall their activities and may not fully understand the concept of physical activity [124].

Though there are some measurement issues associated with objective physical activity tools, they tend to produce less biased estimates when compared to self-reported measures [125]. Instrumental movement devices have become more commonly used over the previous decade. Pedometers are instrumental movement devices which estimate the total number of steps taken but do not measure the intensity of activity [123]. An accelerometer is a motion sensor device which measures movement through acceleration and can measure the duration and intensity of physical activity [123]. Decisions made during data collection and data processing of instrumental movement devices can influence results [126].

As there is no consensus of the analysis and interpretation of accelerometer data, a number of practical measurement issues associated with data collection and data processing need to be considered when conducting a study [126]. The duration of the measurement period should reflect habitual patterns in day to day variability of physical activity and sedentary patterns. In order to capture habitual patterns in children, it has been suggested that 4 to 9 days of data collection are needed including week and weekend days [127]. Non-wear time needs to be considered during processing and refers to periods of noncompliance where an individual does not wear their accelerometer. Definitions are available to help distinguish non-wear time from sedentary time [126]. Invalid data readings need to be considered and are those that are unusual or implausible. There is no consensus on how to define invalid data and different studies use different definitions [128]. The choice of thresholds to define the intensity of activity should be carefully selected as this can influence the amount of time children are categorised at each activity intensity [126].

2.7.2. Levels of physical activity in children

A large proportion of children are not meeting WHO recommended physical activity guidelines [129]. These estimates vary widely within and between countries. Recent self-reported Irish estimates from 10-18 year olds suggested that 19% of primary school and 12% of post primary school children met recommended levels of MVPA [130]. Self-reported data from the Health Behaviour in School Aged Children study 2010 suggested that 31% of 11 year old Irish girls and 43% of 11 year old Irish boys were achieving 60 minutes of MVPA per day [131]. A further pedometer based study in Ireland found that 75% of girls and 62% of boys met daily step count recommendations (>12,000 steps per day for girls and >15,000 steps per day for boys). Using accelerometer data, Riddoch et al, found that only 2.5% of 11 year old British children (0.4% of girls and 5.1% of boys) achieved on average 60 minutes of MVPA per day [132] whereas van Sjuijs et al, 2008 reported that 80% of British boys and 60% of British girls aged 9-10 years achieved 60 minutes per day. Variations in levels of physical activity may reflect varying methods of measurement or definitions of levels of physical activity.

2.7.3. Physical activity and obesity

Associations between physical activity and obesity have been relatively consistent. Most studies have used MVPA to describe physical activity levels. Jiménez-Pavón et al, 2010 reviewed literature on the association between objectively measured physical activity and childhood obesity [133]. The authors suggested that there was strong evidence to suggest that higher levels of physical activity were associated with lower levels of adiposity. The authors also suggested that the evidence in this review was more consistent than previous reviews and that this may be due to the objective nature of the physical activity measurements. A further review by Prentice-Dunn & Prentice-Dunn, 2012 found some mixed findings from cross-sectional studies which examined the association of physical activity and sedentary behaviour on the risk of childhood obesity [134]. Some included studies found that sedentary behaviour was a stronger risk factor for childhood obesity when compared to physical activity. Wilks et al, 2010 assessed prospective studies on the association between measured physical activity and changes in adiposity in children. The authors reported that baseline physical activity may not be an important predictor of changes in adiposity over time in children [135].

Few studies have assessed the full spectrum of physical activity levels and associations with childhood overweight and obesity. Steele et al, [136] reported an inverse association between time spent in moderate, vigorous and total activity with measures of adiposity, reporting that higher intensities of physical activity were more strongly associated with lower adiposity, independent of sedentary time. Chaput et al, [137] reported similar findings to those found by Steele et al, but suggested that sedentary time was not associated with adiposity.

2.8. Sedentary behaviour

As time spent at sedentary behaviours has increased in recent years due to cultural, social and economic change, there has been increasing interest in the association between sedentary behaviour and childhood obesity [138]. Sedentary behaviour can be defined whereby very little energy is being expended (≤1.5 METS), a person is sitting or lying down and is awake [139]. Similar to physical activity, sedentary behaviour has multiple dimensions including total time spent sedentary and type of sedentary behaviour. Types of sedentary time include television (TV) viewing, the use of computers, use of video games and sitting. Sedentary time and behaviour data can be measured by self-report or through objective measurement tools including accelerometers. A number of studies have used a proxy measure of sedentary time including time spent watching TV when assessing risk factors for childhood obesity [140]. Current American recommendations suggest that children should spend no more than two hours per day at screen time activities [141].

Some recent evidence now suggests that time spent sedentary is an important determinant of childhood overweight and obesity, independent of time spent at MVPA [142]. This suggests that physical activity and sedentary time are separate constructs reflecting that sedentary time can have a specific impact on obesity in children independent of MVPA [143]. For example, sedentary time may influence obesity risk due to increased energy intake whilst sitting. A higher energy intake may result if foods are consumed whilst sedentary or if exposure to food and drink advertisements influences food choice [144-146]. Blundell, 2011 [147] suggested that sedentary time may be associated with weight gain as a result of poorly regulated appetite.

2.8.1. Sedentary behaviours and obesity

A number of studies have reported an association between screen time activities, particularly TV viewing and childhood obesity [148-150]. However, many cross-sectional studies which have found an association between TV viewing and obesity in children have reported small effect sizes and measurement issues which may play a role in explaining this [151]. Braithwaite et al, 2013 reported a dose response association between TV viewing and BMI [152]. Lane et al, 2013 reported an association between screen time and the risk of childhood obesity in Irish children [153]. The authors reported that children who spent greater than 3 hours per day at screen time activities were at an increased risk of overweight and obesity than children who spent less than 3 hours per day at screen time activities [153].

However, as screen based activities only makes up a proportion of total sedentary time, an increasing number of studies are using accelerometer derived data to estimate total sedentary time. To date, the association between total sedentary time and the risk of childhood overweight and obesity remains equivocal [136, 137, 154-156]. Herman et al, 2014 report that overweight and obese children spend more time sedentary (accelerometer based data) and spend more time at screen time activities when compared to normal weight children [157]. However, Carson et al, 2011 reported that overall volume of sedentary behaviour was not associated with waist circumference whereas increased TV viewing time was associated with a larger waist circumference in 10-16 year olds. Kwon et al, 2013 [158] also reported that sedentary time did not impact on adiposity independent of MVPA. Low between children variability in time spent sedentary may explain these inconsistent findings [156].

2.9. Family level factors for childhood overweight and obesity

A combination of shared family genetic, environmental and socio-economic factors can play an important role in determining child weight status [159]. Rapid increases in obesity rates suggest that shared family behaviours within the home environment can influence the risk of obesity. The shared family behaviours are thought to be influenced by parental lifestyle choices and behaviours including feeding practices, meal patterns, level of fast food consumption, media use and family based physical activity [160-164]. For example, risk factors can cluster within the family [165]. Steffen et al, 2013 recently reported parent child correlations between weight status and between screen time [164]. In the sections below, parent weight status and family SES are discussed as factors which reflect important aspects of the shared family environment.

2.10. Parent weight status

Parent weight status can be measured using a number of anthropometric measures though BMI is commonly used to define overweight and obesity. Parent BMI can either be self-reported or objectively measured. Self-reported data tends to be inaccurate as people often overestimate their height and underestimate their weight [166]. The WHO definitions based on BMI are commonly used to describe adults as normal weight (>18.5 to <25 kg/m^2), overweight (≥25 to <30 kg/m^2) or obese (≥30 kg/m^2) [1].

Parental obesity has been described as a predominant risk factor for childhood obesity [167-169]. Both maternal and paternal weight statuses have been reported to be predictive of child weight [170, 171]. The relationship between parent weight status and child weight status has been found to be slightly stronger for mothers than for fathers [172, 173]. The Kiel Obesity Prevention Study found that 32% of obese children had an obese mother while 29% of obese children had an obese father [173].

Many studies have examined the extent to which parental overweight and obesity is associated with child weight [174]. The findings suggest that parental overweight increases the risk of childhood obesity and that there may be a graded association between parent and child weight status [175]. However, many studies have used self-reported parental weight. Wake et al, 2006 used self-reported data and found that having an overweight mother doubles the odds of a child being overweight or obese at age 5 when compared to children with a normal weight mother. Having an obese mother tripled the odds of obesity at age five in this study [176]. Ochoa et al, 2009 also used self-reported data and found that children with two obese parents were over eight times more likely to be obese when compared to children with two normal weight parents [177].

Fewer studies have used measured parent weight status and of these a limited number have used a combined single index to assess how parental weight status influences child weight status. Garipagaoglu et al, 2009 and Whitaker et al, 2010 found similar results where children with obese parents were 12 times more likely to be obese compared to children with normal weight parents [175, 178]. At age 8, Magarey et al, 2003 found that children with 2 overweight parents were 8 times more likely to be overweight compared to children with normal weight parents [179]. Francis et al, 2007 presented similar findings in children aged 13 [180]. Perez-Pastor et al, 2009 presented results separately for boys and girls aged 8. Results were presented based on the weight status of the same sex parent. The study found that girls were 10 times more likely to be obese if their mother was obese and boys were 6 times more likely to be obese if their father was obese [181].

2.11. Socio-economic status

Socio-economic factors are associated with health inequalities [182]. SES represents the social standing and socio demographic context in which an individual lives [182]. Child or family level SES can be measured using a number of indicators including parental education, social class or parental income. The indicator used to describe the relationship between SES and obesity may influence the association [183] as SES may contribute to multiple dimensions of the shared family environment. For example, SES may influence dietary behaviour through level of nutritional knowledge, food affordability or access to food stores [184-187]. Each of these factors may operate via different pathways to impact on diet and obesity risk.

Though a number of studies have suggested that children from a lower SES have a higher prevalence of obesity than children of a high SES [188-190], evidence of an association between SES and childhood obesity remains equivocal. This was highlighted in a literature review by Sobal and Stunkard, 1985 [9]. Shrewsbury and Wardle, 2012 recently published a systematic review on the association between measures of SES and adiposity in children. Of the included studies, 42% found an inverse association between SES and adiposity, 27% of studies found no association and 31% of studies found mixed findings (either inverse or no association) across subgroups of the included populations (type of SES indicator, adiposity indicator, gender etc.) [183].

Findings from a multicentre study of eight European countries found an inverse gradient between SES and childhood obesity in five of the participating countries. The study suggested that parental education and parental occupation contributed more to the gradient than household income [191]. Shrewsbury and Wardle, 2012 also reported that parental education may be most consistently associated with childhood obesity [183].

2.12. Environmental level factors for childhood overweight and obesity

The environment is a broad term which describes the physical, societal and governmental level structures in which people live. The environment can influence lifestyle choices and obesity risk [192]. This section briefly describes the built environment with a specific focus on the impact of the local environment on diet and obesity.

2.13. Built environment

The built environment is the term coined to describe characteristics of an individual's environment which have been modified or are human-made [193]. Characteristics of the built environment can either promote or hinder lifestyle choices associated with obesity including diet or physical activity [194]. Factors which hinder positive lifestyle choices can influence the risk of obesity via a number of mechanisms.

The built environment encompasses physical, social and economic aspects of the local environment. Each of these aspects of the environment can influence behaviours and obesity risk [195]. Physical aspects include land use, public transport options and the availability of local resources including food stores and recreational facilities. Social and economic aspects can influence the level of resources available to local residents. For example, more disadvantaged areas may have poorer infrastructure or less transportation options than more affluent areas

[11, 193, 196]. Perceived neighbourhood safety and access to green space in the community may influence physical activity levels [193]. Safer areas and areas with greater connectivity of pathways may influence greater levels of walking or cycling whereas areas perceived as being less safe or that may have greater levels of antisocial behaviour may hinder against people choosing more active forms of transport [11].

2.13.1 Overview of food availability

The food environment is one aspect of the built environment which can influence diet and obesity. The food retail sector in developed countries has changed dramatically since the 1960s. For example, cultural and socio-economic shifts at that time such as increasing numbers of women in the workforce and increasing transport options led to a greater demand for value for money and for a wider range of food products [197]. This resulted in an increasing number of supermarkets and this competition led to a decline in the number of smaller food stores. More recently, discount stores such as Lidl and Aldi, which tend to stock a limited amount of products at low price, have entered the Irish and UK market [197, 198].

The local food environment can influence food choice by restricting the availability or affordability of healthy foods [76, 197, 199, 200]. For example, the term 'food desert' was first coined in Scotland in the early 1990s to describe well populated urban areas where residents have little access to an affordable and healthy diet. Typically 'food deserts' are associated with a low income or with living in a deprived neighbourhood [201]. Lack of supermarkets in poorer communities has been described as a predominant factor associated with poor food choice and affordability [197].

The concept of 'food deserts' has led to a new field of research on the impact of food access on health at an individual and household level [197]. To date, the focus on food access research has focused on the number, type and size of stores within a geographically defined area. In addition, the cost, range and quality of foods available in stores within these geographically defined areas have also been explored [197]. Food accessibility can be assessed using a number of methods of measurement including proximity and density. Proximity is the distance between a food outlet and a second location often the home or school. Density is the number of food stores within a predefined radius of a predefined location (eg. the home). The proximity and density of food outlets with the local environment may influence food choice by either increasing or reducing food choices available [202].

2.13.2 Food availability and the retail sector in Ireland

The Irish grocery sector can be divided into three groups: 'vertically integrated retailers', 'group and symbol stores' and 'independent retailers'. 'Vertically integrated retailers' own or operate multiple retail outlets (subdivided into ‘multiples’ and ‘foreign discount stores’). ‘Multiples’ are Dunnes Store and Tesco while ‘foreign discount stores’ include Aldi and Lidi. ‘Affiliated retailers’ typically own and operate one retail outlet under a retail brand or franchise (known as ‘group and symbol stores’). Examples include Supervalu and Centra. ‘Independent retailers’ include independent retailers, forecourt garages and newsagents.

‘Vertically integrated retailers’ have the largest share of the Irish market and are commonly used by all social groups though there is a price differential between food outlet types. Different food outlets also stock varying ranges of food types in Ireland. Foreign supermarkets have been found to be the cheapest food outlets [203]. Foreign supermarkets tend to stock a smaller range of foods than other supermarkets. Socio-economic differentials have also been observed in Ireland where low income groups shop more in smaller convenience stores [204-207]. Convenience stores tend to stock less healthy food such as fruit, vegetables and whole grain products and tend to stock a larger proportion of processed, energy dense foods. Convenience stores also tend to be more expensive than supermarkets [198, 207].

Limited research has been conducted in Ireland to explore the impact of food access in the local area on dietary intake and obesity. However, there is some evidence from other countries and a synopsis of this evidence is outlined below and further literature is available in Chapter 9.

2.13.3 Food availability in the local area, diet and obesity

Most of the research on the food environment is from North America where findings suggest that healthy foods are more expensive and less available in poor areas compared to wealthy areas. Poorer areas were found to have less supermarkets, more convenience stores and more fast food outlets than the wealthier areas [208-211]. Morland & Evenson, 2009 reported lower levels of obesity in areas with supermarkets and higher levels of obesity in areas with convenience stores or fast food outlets [212]. Spence et al, 2009 reported that proximity to convenience stores and fast food outlets was associated with obesity risk in Canadian adults [213]. Fewer studies in the USA have explored how the food environment impacts on diet and obesity risk in children and adolescents. However, similar trends have been observed in American adolescents [214].

To date, research from other regions remains equivocal. Some studies have found positive associations, others have found no associations and a small number of studies have shown counterintuitive findings between dietary intake and the local food environment [215]. For example, Mason et al, 2012 found strong evidence of an association between the purchase of fruit and vegetables and the proportion of healthy food outlets in an area in Australia [216]. On the other, Simmons et al, failed to find an association between access to takeaways and obesity risk in rural areas of Australia [217]. Few studies have assessed the impact of the local environment on diet and obesity in children [202].

2.14. SUMMARY

Obesity is an excessive or abnormal fat accumulation which poses a threat to the health and wellbeing of children. Globally, prevalence rates have increased rapidly between the 1970s and 1990s. There is a considerable evidence base on risk factors for childhood overweight and obesity. However, risk factors for obesity have traditionally been poorly measured. This is partly due to practical and epidemiologic challenges associated with measuring diet, physical activity and obesity in children.

Due to the complex nature of obesity and substantial error associated with measuring risk factors for obesity, there is an urgent need to utilise more robust and objective measurement tools. This is particularly true in Ireland where objective data are scarce. In order to develop an understanding on how to reverse the current childhood obesity epidemic, it is essential we understand the complex set of multilevel influences associated with childhood overweight and obesity. Risk factors explored in this thesis have been described in this chapter and further details on each risk factor are presented in the results chapters (see Chapters 5-9).

This thesis will use a social ecological framework to examine multilevel risk factors associated with childhood overweight and obesity in Ireland, with a particular focus on diet and physical activity. This thesis will explore individual level lifestyle factors along with the wider family and environmental context in which children live. A number of practical issues associated with the design, conduct, and analysis of diet, physical activity and obesity data are considered and described throughout this thesis. This thesis aims to contribute to the current evidence on the direction, magnitude and contribution of risk factors associated with childhood overweight and obesity.

3. TRENDS AND PREVALENCE OF OVERWEIGHT AND OBESITY IN PRIMARY SCHOOL AGED CHILDREN IN THE REPUBLIC OF IRELAND FROM 2002-2012: A SYSTEMATIC REVIEW (PAPER 1)

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3.1. Abstract

Background

The prevalence of childhood overweight and obesity in developed countries appears to be levelling off. As trends in childhood obesity prevalence has not been examined over the past decade in the Republic of Ireland, this systematic review aims to compile and synthesise all available information on the prevalence of overweight and obesity in primary school aged children between 2002 and 2012.

Methods

Systematic review of published and grey literature containing data on objectively measured height and weight. Inclusion criteria included studies where data was collected between 2002 and 2012 from at least 200 primary school aged children in the Republic of Ireland. Database searching, Google searching, reference searching and contact with obesity experts was undertaken. Overweight, obesity and morbid obesity were defined using standard IOTF definitions. Study quality was assessed.

Results

Fourteen studies (16 prevalence estimates) met the inclusion criteria. The combined prevalence of overweight and obesity within the studies ranged from 20-34%. No significant trend in overweight prevalence over time was observed (p=0.6). However, there was evidence of a slight decrease in obesity prevalence over the

period (p=0.01), with a similar though non-significant decline in the prevalence of morbid obesity (p=0.2).

Conclusion

The findings of this systematic review require cautious interpretation though the prevalence of childhood overweight and obesity in the Republic of Ireland has reached a plateau and may be falling. These findings provide some ground for optimism though the current plateau is at an unacceptably high level. Thus population based preventive strategies need to be sustained and intensified.

3.2. Background

In the latter three decades of the 20th century, a two to three fold increase in overweight and obesity prevalence rates in school aged children was reported in many industrialised regions. This includes countries in North America and Western Europe [2]. By the year 2000, estimates suggested that between 25-33% of all children in many developed countries were either overweight or obese [31, 37] and future projections anticipated prevalence rates would continue to increase significantly [33].

However, recent evidence from some developed countries suggests that childhood overweight and obesity prevalence rates have stabilised since the early 2000s [218, 219]. Olds et al, [220] collated data from 467,294 children from 9 countries (including countries from Western Europe, North America, Oceania and Asia) and separately assessed overweight and obesity trends over time. The authors found that trends in both overweight and obesity prevalence appeared to be stabilising between 1995 and 2008. Rokholm et al, [32] conducted a systematic review and assessed the prevalence of childhood obesity in 17 countries (including countries in Western Europe, North America and Australia) since the year 1999. While there was some conflicting evidence, overall the findings suggested that obesity prevalence had stabilised in many developed countries though patterns were less consistent amongst lower socio-economic groupings.

Perry et al, [221] collated data from three large scale national surveys on the height and weight of Irish children between 1948 and 2002. The findings indicated that the weight of Irish children had increased disproportionally to their height. In 2008, the WHO childhood obesity surveillance initiative commenced in Ireland and this initiative will provide ongoing data on the height and weight of Irish children aged 7 [222]. However, trends in childhood overweight and obesity in the Republic of Ireland have not been examined over the past decade. The prevalence of morbid obesity in Irish children also remains unknown. Therefore, this systematic review aims to objectively synthesise all available information on the prevalence of overweight and obesity (including morbid obesity) in primary school aged children in the Republic of Ireland over a ten year period from 2002-2012.

3.3. Methods

3.3.1. Search strategy

The search strategy is summarised in Figure 2 with further details available at http://www.biomedcentral.com/1471-2458/14/974/additional. Medline, EMBASE, Academic search complete and CINAHL were systematically searched for relevant literature in April and May 2013. For each database, searching was conducted using a combination of the following search terms: obesity, overweight, obese, body mass index, BMI, Ireland, Irish, child*, school children, schoolchildren, pediatr*, paediar*, girls, boys, prevalence, rate, trend, increase, decrease. Search terms were combined using the AND or OR operators. Limits were applied on year of publication (from 2002 onwards) and age (primary school age) of participants.

A Google search was conducted in May 2013 using the search terms: prevalence, child, obesity, Ireland. Google advanced search commands were applied using the 'site or domain' option with .ie webpage's searched only. The first 20 pages were searched for relevant literature. Publically available Irish databases or national agencies websites (Irish Social Science Data Archive, Safefood, The Health Well, Department of Health and Children's Irish child health database) known to the authors of this review and available on the Internet were searched for relevant literature in April and May 2013. A number of obesity experts working in Ireland were identified by the authors of this systematic review. Each expert was contacted either by email or via an announcement made at an Irish obesity action meeting held in June 2013 (http://www.safefood.eu/Professional/Nutrition/All-island-Obesity-Action-Forum.aspx). Information was sought on any data sources not located during the database searching. Data sources known to the authors of this review were also considered for inclusion. A reference search of all eligible papers was conducted to identify additional literature. Findings from one included study (the WHO European Childhood Obesity Surveillance programme) were updated during the writing of the review and the updated findings included in the current review [223].

3.3.2. Inclusion criteria

Inclusion criteria for this review were as follows:

1. Studies conducted in the Republic of Ireland where data collection was undertaken between 2002-2012;

2. Cross-sectional or cohort studies where height and weight were objectively measured;

3. Studies reporting overweight and obesity prevalence estimates using IOTF [27] definitions for BMI or where data was available to calculate BMI;

4. Studies including at least 200 children of a primary school age (approximately 4-12 years).

Peer-reviewed publications, grey literature and baseline data from population based intervention studies were considered for inclusion. Studies containing participants from Northern Ireland only, self-reported data or which reported the effect of a treatment or intervention for childhood obesity were excluded.

3.3.3. Quality assessment and data extraction

The methodological quality of all included studies was assessed and extracted by two independent reviewers (Eimear Keane, Janas M Harrington). Any disagreements were resolved by consensus. Appendix 1 (Table 29) provides an outline of the quality assessment criteria and critical appraisal of each study can be found at http://www.biomedcentral.com/1471-2458/14/974/additional. Eight criteria were used which were adapted from those outlined by Radulescu et al, 2009 [224] for assessing the quality of prevalence studies. The quality of included papers were categorized as 'high' if 7-8 criteria were met, 'moderate' if 5-6 criteria were met and 'low' if 4 or less criteria were met.

3.3.4. Statistical analysis

Data analysis for this review was conducted in Stata 12 IC (StataCorp LP, USA). Where raw data was provided, children were categorised using the zbmicat function (a Stata add-on program) as normal weight, overweight or obese using age and gender specific IOTF definitions [225]. Year of data collection was ranked from oldest to newest and Cuzick's non-parametric trends test was used to conservatively test for trends in overweight and obesity prevalence over time. Trends were assessed separately for all studies, nationally based and regionally based studies. Within the included studies, trends in overweight and obesity over time were assessed separately for girls and boys. The included studies were grouped into 3 independent categories based on the age range of the participating children as 4-7.9 years only, 8-13.9 year only or 4-13.9 years. Trends in overweight and obesity were then assessed separately within each of the age groups. Three of the included studies had raw data available (including the CCLaS Study [see Chapter 4 for more detail]) [226, 227] to estimate the prevalence of morbid obesity (BMI cut-off of 35 km/m^2) using extended IOTF definitions [30]. A fourth study with available data was excluded as height and weight measures were truncated [228]. Children were classified as morbidly obese based on gender and 6 month age category.

3.4. Results

3.4.1. Identification and selection of studies

Five hundred and thirty five titles were retrieved from electronic database searching and 11 from the other sources searched. Duplicate titles were removed (N = 33) and 513 titles/abstracts were reviewed and considered for inclusion. After initial screening of titles and abstracts, 19 full texts were retrieved and read for relevance. Electronic database searching resulted in 8 studies being identified for inclusion, of which one study was updated during the writing of this systematic review. One further relevant study was identified during reference searching, 3 from contact with obesity experts and 2 from the authors of this reviews awareness of other grey literature sources. Overall, 14 studies (with 16 prevalence estimates reported in 15 papers) met all the inclusion criteria. Figure 2 displays the results of the search strategy.

3.4.2. Description of included studies

Table 1 describes each of the included studies. The included studies were primarily cross-sectional. One study was a retrospective cohort study and two studies were baseline findings from intervention studies. Four studies (6 prevalence estimates) were based on national samples whereas 10 were regional samples. The sample sizes ranged from 204 to 14,036. Table 2 contains details on the methods of measurement and the limitations (which were identified by the authors of this review) of each study. Of the included studies, 5 studies were considered to be of 'high' quality, 9 of 'moderate' quality and 1 of 'low' quality. Table 1 contains the critical appraisal score given to each included studies (see http://www.biomedcentral.com/1471-2458/14/974/additional for more details). Overall, the combined prevalence of overweight and obesity in the national and regional studies ranged from 20-26% and 21-34% respectively.

3.4.3. Prevalence of overweight and trends over time

Figure 3 and Table 3 describe the prevalence of overweight and obesity within each included study. Within the national and regional based studies, the prevalence of overweight ranged from 15-19% and 15-26% respectively. The prevalence of overweight ranged from 17-21%, 15-26% and 15% within the 'high', 'moderate' and 'low' quality studies. No significant trend in overweight prevalence was observed over time among all included studies (p=0.6), national studies (p=0.09) or regional studies (p=0.8).

3.4.4. Prevalence of obesity and trends over time

The prevalence of obesity ranged from 4-7% in the nationally based studies. The prevalence of obesity ranged from 5-11% in the regional studies. The prevalence of obesity ranged from 7-9%, 4-11% and 6% within the 'high', 'moderate' and 'low' quality studies. A small, significant declining trend in obesity prevalence was observed over time when all studies were reviewed (p=0.01). No significant trend over time was observed for the national (p=0.09) studies and a borderline significant trend over time was observed for the regional studies (p=0.05). When overweight and obesity prevalence rates were combined, trends were not significant.

3.4.5. Prevalence of morbid obesity and trends over time

Morbid obesity prevalence estimates were available for three of the included studies. Based on year of data collection from least to most recently collected data, the prevalence of morbid obesity in each of the three studies was 2.2% [229], 1.0% [226] and 0.8% (CCLaS Study). The highest prevalence estimate was reported in the earliest (2002) study. The reduction in estimates over time was not significant (p=0.2).

2.4.6.Prevalence and trends by age and gender

The prevalence of overweight and obesity in the national studies was consistently higher in girls than boys. Within the included studies, a significant trend over time was observed for obesity rates in girls in all included studies (p=0.04) but not in boys (p=0.2). When trends in overweight and obesity prevalence over time were assessed within the studies that collected data in children aged 4-7.9 years only, 8-13.9 years only and from 4-13.9 years, no significant trends were observed.

3.5. Discussion

3.5.1. Main findings

This systematic review aimed to synthesize all available overweight and obesity prevalence data from primary school children in the Republic of Ireland between 2002 and 2012. Fourteen studies (16 prevalence estimates) were included in the review. Due to limited comparability between studies, the results of this review were difficult to interpret. However, similar to trends in other developed countries [32, 230], this review suggests that while childhood overweight and obesity prevalence rates remain high in Ireland, prevalence rates appear to be stabilising.

Within the included studies, no trend in overweight prevalence was observed over time. Overweight prevalence varied slightly (non-significant trend) in the nationally based studies with the lowest prevalence of overweight reported in the study where data was collected most recently [223]. This may reflect the age of the included participants rather than a decrease in the prevalence of overweight. The children who participated in the most recent studies were 7 years of age [222, 223]. Pubertal maturation is associated with an increased BMI [31, 231] and this may partly explain the lower prevalence of overweight and obesity in the later completed study. Alternatively, differences in methodologies between studies may explain findings.

A statistically significant trend over time in obesity prevalence was observed. Obesity prevalence remained constant at 7% in the nationally based studies between 2002 and 2008 with the prevalence of obesity reducing to 4% thereafter. The results from the regionally based studies were difficult to interpret and prevalence rates varied considerably between studies. The quality of some of the regional studies or the generalisability of the study populations may act as an explanation. For example, two of the regional studies [232, 233] were completed in areas of high social deprivation. Thus, higher prevalence rates may have been estimated in these studies as a lower socioeconomic status is associated with an increased risk of obesity [189].

Morbid obesity data was available for three of the included studies. The results suggest that up to 1 in 50 Irish children are morbidly obese. The lower prevalence of morbid obesity reported in the studies where data was collected most recently may reflect that obesity is receiving increasing attention from the media [234], government organisations [235] and from research institutions. This may have increased awareness of the obesity epidemic in the Irish population and acted as a disincentive for obese children and their parents to participate in studies measuring BMI. Alternatively, the lower prevalence of morbid obesity in the most recent study may reflect a small downward shift in the population distribution of BMI in children in the Irish population [236].

To date, few childhood obesity interventions have been implemented in the Republic of Ireland and interventions are unlikely to explain why childhood overweight and obesity rates may be stabilising. Recent interventions in the Republic of Ireland have targeted specific populations such as those who are morbidly obese [237]. Other interventions have targeted specific behaviours associated with obesity including fruit and vegetable consumption [238], physical activity levels [239] or screen time [232]. The magnitude of the problem of childhood overweight and obesity in the Republic of Ireland requires interventions which should be targeted at a population level. Other explanations for our findings include the relatively short time frame of included studies. A greater time period may be required to observe a clear trend in prevalence rates, especially when comparing studies with different sample sizes, age ranges and using varying methods.

3.5.2. Childhood overweight and obesity rates in other developed countries

Though the prevalence of childhood obesity appears to have stabilised in a number of countries, the prevalence of overweight and obesity continues to vary significantly between and within countries. The current prevalence of overweight and obesity in the Republic of Ireland is broadly similar to other European estimates. For example, the EuropeaN Energy balance Research to prevent excessive weight Gain among Youth (ENERGY) Project study measured BMI across seven European countries and found that 25.8% of boys and 21.8% of girls were overweight or obese though prevalence rates did vary from 14% in girls from Belgium to 44% of boys from Greece [240]. Contrary to the ENERGY Project study, the findings of our review suggest that the prevalence of overweight and obesity in the Republic of Ireland is higher in girls than boys. Social and economic factors may help explain why prevalence rates vary between countries. Brug et al. 2012, suggest that socioeconomic factors or cultural factors may play an important role when explaining varying overweight and obesity prevalence rates between countries [241].

3.5.3. Monitoring of overweight and obesity prevalence rates

Monitoring childhood obesity prevalence rates is an important public health measure. In the Republic of Ireland, trends in childhood overweight and obesity had not been routinely monitored prior to the introduction of the WHO European Childhood Obesity Surveillance programme in 2008. Three phases of WHO surveillance data have now been collected in 2008, 2010 and 2012 [222]. Over time, this data will create a national database which will be comparable to surveillance data collected in other European counties [35].

All children in senior infants (year two of enrolment) in primary schools in the Republic of Ireland receive a health check. Measurement of height and weight is to be included in a small subsample of schools. Based on this pilot project, height and weight may be added to this routine health check. This would provide valuable information on the height and weight of Irish children. However, ongoing surveillance initiatives do not reduce the value of other studies collecting objective height and weight data though it is essential that methods used between studies are standardised.

3.5.4. Recommendations for study reporting

This review has resulted in two recommendations for study reporting. Firstly, confidence intervals (CI) or standard errors should be reported with prevalence estimates. This did not commonly occur in the included studies. Secondly, studies should provide sufficient detail which would allow for replication of the methods used.

3.5.5. Strengths and limitations

A comprehensive search strategy was used to locate relevant literature and contact with obesity experts in Ireland resulted in some additional studies being identified. A critical appraisal tool was adapted to assess the quality and potential sources of bias within each included study. However, a standard critical appraisal tool to access the quality of studies reporting prevalence estimates needs to be developed. This review also has a number of limitations. The interpretation of the findings of this review was difficult due to varying methods used in the included studies. As detailed above, few of the included studies reported confidence intervals or standard errors. It was therefore difficult to interpret the accuracy of the point estimates.

3.5.6. Conclusion

Though this review includes studies from a relatively short, 10 year time frame, the prevalence of overweight and obesity in school aged children in the Republic of Ireland appears to be stabilising. In the absence of routinely measured data from large and representative population samples, caution is needed in the interpretation of these findings. There is a clear need to agree and disseminate SOPs and methods for the conduct of studies on the prevalence of overweight and obesity in childhood with particular reference to the issues of sampling and response rates. Although the findings provide some grounds for cautious optimism, one in four Irish children remains overweight or obese. Thus, it is clear that childhood overweight and obesity will remain an urgent priority issue for public policy for the foreseeable future.

Figure 2. Flowchart of studies included in the review

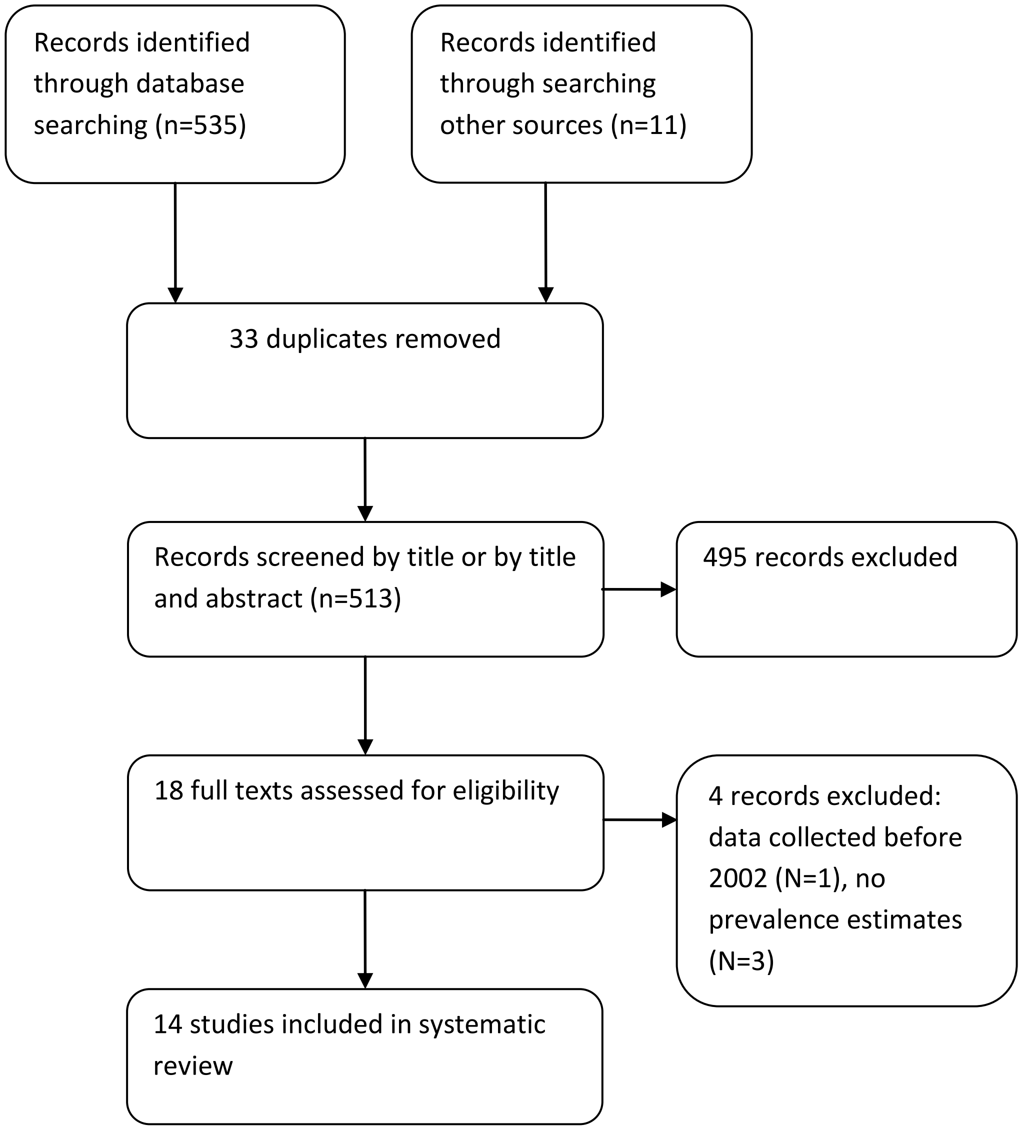


Table 1. Descriptive information of included studies

Author	Data collection years	Estimating prevalence primary aim of study	Sample size#	National or regional data	Age	Setting	Response Rate	Design	Sampling	Study quality (out of 8)
Nationally based data										
Whelton et al, 2006 [227]	2001-2002	Yes	14036	National	4-13	Primary schools	68% of children	Cross-sectional	Clustered sampling with schools as the clustering unit. Children were randomly selected on the basis of age, gender, location of school and water type. Primary school children in junior infants, second and sixth class (year 1, 4 & 8 of enrolment) were invited to take part	6
O'Neill et al, 2007 [25]	2003-2004	Yes	596	National	5-12	Primary schools	66% of children	Cross-sectional	A list of primary schools was obtained from the Dept of Education and Science. Schools were categorised by location, gender, size and disadvantaged status. Schools were randomly selected from each category and children randomly selected and invited to take part	5
Layte & McCrory, 2011 [242]	2007-2008	Yes	8136	National	9.0-9.9	Home	57% of children	Cross-sectional analysis of a longitudinal study	In stage one, primary schools were randomly selected using a probability proportionate to size (PPS) sampling method and in stage two a random sample of age eligible children from within each school were invited to take part	7

Author	Data collection years	Estimating prevalence primary aim of study	Sample size#	National or regional data	Age	Setting	Response Rate	Design	Sampling	Study quality (out of 8)
Heavey et al, 2009 [222]	2008	Yes	2420	National	7.0-7.9	Primary schools	72% of children	Cross-sectional, round 1 of WHO COSI programme	A nationally representative sample of primary schools was selected using a PPS sampling strategy. Children in first class (year 3 of enrolment) were recruited to participate. One class of first class children were selected from large schools	7
Heinen et al, 2014 [223]	2010	Yes	996	National	7.0-7.7	Primary schools	64% of children	Cross-sectional, round 2 of WHO COSI programme	Schools who took part in round 1 [222] of this surveillance initiative were invited to take part in round 2. Only children aged 7 in first class were considered in this current analysis. One class of first class children were selected from large schools	6
Heinen et al, 2014 [223]	2012	Yes	991	National	7.0-7.7	Primary schools	55% of children	Cross-sectional, round 3 of WHO COSI programme	Schools who took part in round 1 [222] of this surveillance initiative were invited to take part in round 3. Only children aged 7 in first class were considered in this current analysis. One class of first class children were selected from large schools	6
Regionally based data										
McMaster et al, 2005 [243]	2001-2002	Yes	328	Regional (Counties Leitrim and Cavan)	4.2-7.9	Primary schools	91% of records had height & weight measures	Retrospective cohort	All senior infants (year 2 of enrolment) from all schools in the former North Western Health Board area. Paper copies of school health records were retrospectively hand searched for height and weight data in March 2003	7

Author	Data collection years	Estimating prevalence primary aim of study	Sample size#	National or regional data	Age	Setting	Response Rate	Design	Sampling	Study quality (out of 8)
Harrison et al, 2006 [232]	2003	No	312	Regional (South-East of Ireland)	9-11	Primary schools	99% of children	Baseline findings from a health education intervention	Schools in areas of social disadvantage located in the South East of Ireland were recruited to participate and children from 4th class (year 6 of enrolment) were invited to partake	5
Evans et al, 2010 [244]	2004-2007	Yes	3493	Regional (County Mayo)	6.0-6.9	Primary schools	99.7% of children	Cross-sectional	All children from all 189 primary schools in County Mayo had height and weight measures taken as part of the school health check between February 2005 and June 2008	7
Barron et al, 2009 [245]	2007	Yes	969	Regional (County Kildare)	4.5-13.5	Primary schools	83% of children	Cross-sectional	Data collected from 2 single sex primary schools in a town in County Kildare as part of a larger research project	5
Murrin et al, 2012 [246]	2007-2008	No	529 (at follow up)	Regional data (Counties Dublin and Galway)	5-7	Home	62% of mothers at follow-up	Cross-sectional analysis of a prospective observational cross-generational linkage cohort	Sample of 1124 expectant mothers recruited at 1st antenatal hospital visit in 2 hospitals over an 18 month period from 2001-2003 [247]	7
Belton et al, 2010 [248]	2008	No	301	Regional (greater Dublin)	6-9	Primary schools	97% of children	Cross-sectional	Four mixed gender schools from the greater Dublin area were selected to take part in the study	3

Author	Data collection years	Estimating prevalence primary aim of study	Sample size#	National or regional data	Age	Setting	Response Rate	Design	Sampling	Study quality (out of 8)
Fitzgerald, 2010 [249]	2008-2009	No	204	Regional (West of Ireland)	9-12	Primary schools	58% of children	Cross-sectional	Primary schools were randomly selected from the Department of Education and Science list of schools and invited to take part in the study. All children in 4th to 6th class (years 6-8, of enrolment) were invited to take part	6
HSE Meath, 2009 [226]	2009	Yes	1468	Regional (County Meath)	11-13	Primary schools	63% of children	Cross-sectional	A complete sample of primary schools from County Meath were invited to partake and all children in 6th class (year 8 of enrolment) of participating schools invited to take part	6
Hollywood et al, 2012 [233]	2009	No	537	Regional (County Dublin)	4-12	Primary schools	Details not provided	Baseline findings from a prospective cohort study	Primary school children from urban disadvantaged areas located in Revitalising Areas by Planning Investment and Development (RAPID) areas in Dublin took part in study. All children in Junior infants to 5th class (year 1- 7 of enrolment) were invited to take part	5

Author	Data collection years	Estimating prevalence primary aim of study	Sample size#	National or regional data	Age	Setting	Response Rate	Design	Sampling	Study quality (out of 8)
CCLaS Study	2012-2013	Yes	1068	Regional (County Cork)	8-11	Primary schools	65% of children	Cross-sectional	A list of primary schools was obtained from the Dept of Education and Science website. Schools were recruited using a PPS sample (with further purposive sampling) of Cork city primary schools and all rural schools from one area in Cork County were invited to partake. All children in 3rd and 4th class (year 5 and 6 of enrolment) were invited to take part	6

#Sample sizes only include valid number of age eligible participants who provided valid objective height and weight measures

Table 2. Details on method of measurements and limitations of the included studies

Author	Data collection year(s)	Height measure	Weight measure	Method of measurement	Measurement personnel	Limitations ^
Nationally based data						
Whelton et al, 2006 [227]	2001-2002	Leicester portable height measure	Soehnle 7403 Mediscale	Height was measured to the nearest 1 decimal point in centimetres (cm) and weight to the nearest 1 decimal point in kilograms (kg). Shoes, heavy clothing and headgear were removed for measures	Trained researchers took measures using a standard protocol	Response rate not adequate and no information given on non-responders
O'Neill et al, 2007 [25]	2003-2004	SECA Leicester height measure	SECA 770 digital weight scales	Height was measured in the Frankfurt plane position to the last complete millimetre (mm) and weight to the nearest 0.1kg. Light indoor clothing was worn for measures without shoes, hair ornaments, pony tails undone and empty pockets	Qualified nutritionists took measures	Response rate not adequate, no information given on non-responders and methods to reduce observer bias not outlined
Layte & McCrory, 2011 [242]	2007-2008	Leicester portable height measure	SECA 761 flat mechanic scales	Height was measured to the nearest mm and weight to the nearest 0.5kg. Light clothing was worn for measures	Trained researchers took measures	Response rate not adequate and no information given on non-responders**
Heavey et al, 2009 [222]	2008	SECA 214 portable stadiometer	SECA 872 weighing scales	Height was measured to the last complete mm and weight to the nearest 0.1kg. Light indoor clothing was worn for measures without shoes, hair ornaments, pony tails undone and empty pockets	Trained researchers took measures using a standard protocol	Response rate not adequate and no information given on non-responders

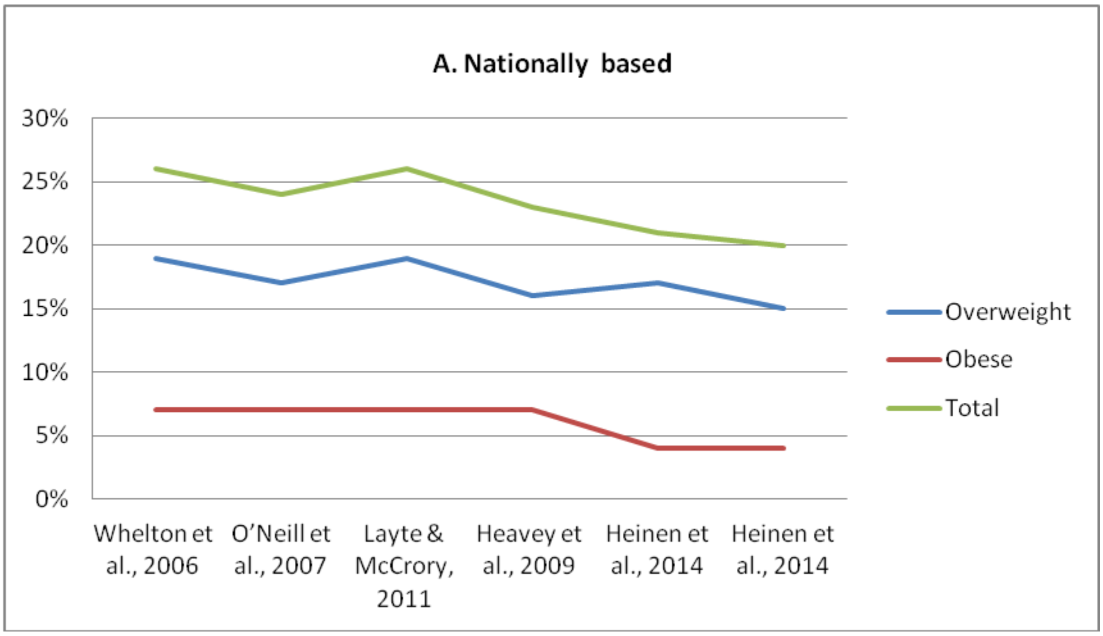
Author	Data collection year(s)	Height measure	Weight measure	Method of measurement	Measurement personnel	Limitations ^
Heinen et al, 2014 [223]	2010	SECA 214 portable stadiometer	SECA 872 weighing scales	Height was measured to the last complete mm and weight to the nearest 0.1kg. Light indoor clothing was worn for measures without shoes, hair ornaments, pony tails undone and empty pockets	Trained researchers took measures using a standard protocol	Response rate not adequate and no information given on non-responders
Heinen et al, 2014 [223]	2012	Leicester height measure	HD-305 Tanita weighing scales	Height was measured to the last complete mm and weight to the nearest 0.1kg. Light indoor clothing was worn for measures without shoes, hair ornaments, pony tails undone and empty pockets	Trained researchers took measures using a standard protocol	Response rate not adequate and no information given on non-responders
Regionally based data						
McMaster et al, 2005 [243]	2001-2002	Leicester height measure	Hansen digital weight scales	Height measured to the nearest 0.5cm and weight to the nearest 500g. Light clothing was worn for measures without shoes, jackets and headgear	Two school nurses took measures using a standard protocol	No information given on non-responders
Harrison et al, 2006 [232]	2003	Seca Leicester height measure	Seca digital floor scales	Children wore light clothing, without shoes for measures	Researchers were trained in anthropometry	Sampling method unclear, no information given on non-responders and not enough detail provided on method of measurement

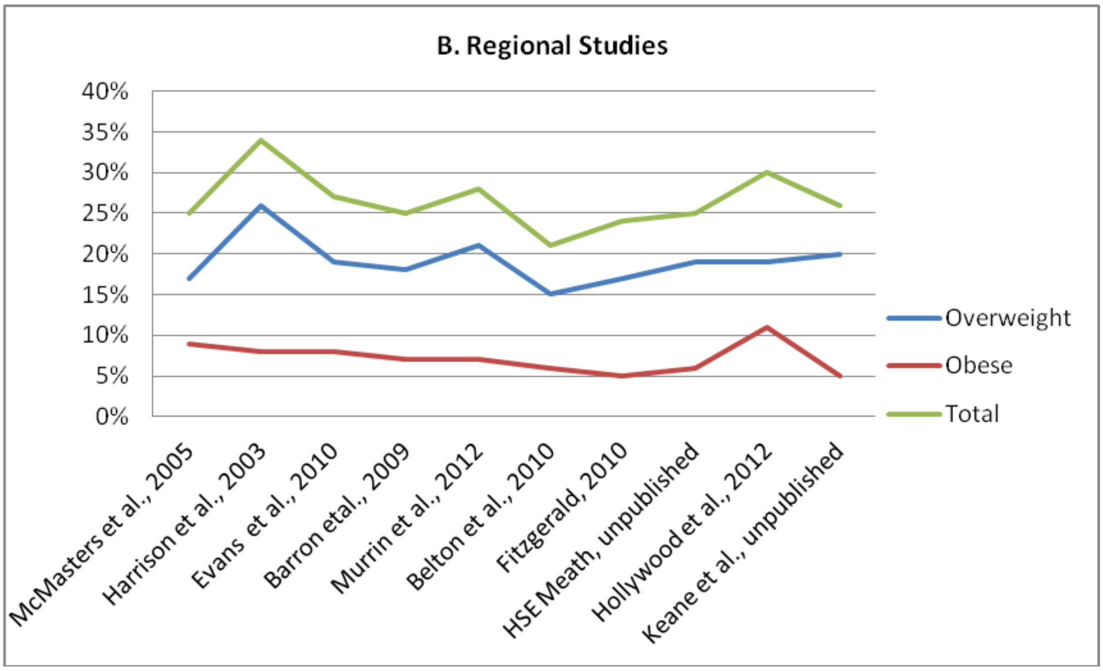
Author	Data collection year(s)	Height measure	Weight measure	Method of measurement	Measurement personnel	Limitations ^
Evans et al, 2010 [244]	2004-2007	Leicester height measure	Tanita solar weight scales	Height was measured to the nearest 0.1cm and weight to nearest 0.1kg using a standard protocol [250]	Trained public health nurses took measures. Intra-observer variability was measured	No information given on non-responders
Barron et al, 2009 [245]	2007	Leicester height measure	Tanita WB-100 digital medical weighing scales	Children wore tracksuits, without shoes for measures	One qualified paediatric nurse took all measures	Sampling method used not clear, no information given on non-responders and not enough detail provided on method of measurement
Murrin et al, 2012 [246]	2007-2008	Leicester height measure	Tanita digital weight scales model HD305	Height was measured to the nearest 1cm and weight to the nearest 0.1kg. A standard protocol was used	Trained researchers took measures using standard procedures	Response rate not adequate
Belton et al, 2010 [248]	2008	SECA Leicester height measure	SECA heavy duty scales	No details given	No details given	Sampling method unclear, no information given on non-responders, height and weight measurements methods used not described, inadequate detail on equipment used and efforts to reduce observer bias not stated

Author	Data collection year(s)	Height measure	Weight measure	Method of measurement	Measurement personnel	Limitations ^
Fitzgerald, 2010 [249]	2008-2009	Leicester height measure	Seca 899 weight scales	Height was measured to the nearest 0.1cm in the Frankfurt plane position and weight to the nearest 0.1kg. Measures were taken without heavy clothing and shoes	Standard procedures were used. Intra observer variability was tested	Response rate not adequate and no information given on non-responders
HSE Meath, 2009 [226]	2009	Leicester height measure	Soehnle 7403 Mediscale	Height was measured in the Frankfurt plane position to the nearest 1 decimal point in cm and weight to the nearest 1 decimal point in kg. . Measures were taken without shoes and without excessive clothing	Researchers trained prior to data collection. Inter examiner agreement was tested	Response rate not adequate and no information given on non-responders
Hollywood et al, 2012 [233]	2009	SECA Leicester portable height measure	SECA 875 digital flat scales	Height was measured in the Frankfurt plane position. Measures were taken in stockings without heavy outdoor clothing	One trained children's nurse took all the measures	Sampling method unclear, response rate not adequate, no information given on non-responders and not enough detail provided on method of measurement
CCLaS Study	2012-2013	Leicester portable height measure	Tanita WB100MA mechanic scales	Height was measured in the Frankfurt plane position to the nearest mm and weight to the nearest 0.1kg. Measures were taken without shoes and in light clothing	Trained researchers took measures using standard procedures	Response rate not adequate and no information given on non-responders

** The data was probability weighted prior to analysis to account for the complex sampling design. This involved the structural adjustment of the study sample to the population level whilst maintaining the case base of participating children, ^ The limitations outlined in this Table were identified by the authors of this systematic review during critical appraisal of each study.

Figure 3. Prevalence of childhood overweight and obesity within the (A) nationally and (B) regionally based studies





Footnotes: Studies are presented by year of data collection. The study on the left represents the prevalence of overweight and obesity from the study which collected data least recently. The study which collected data most recently is presented on the right.

Table 3. Prevalence of overweight and obesity in the included studies#

Study	Data collection year(s)	Sample size	Age range	Prevalence of overweight			Prevalence of obesity (including morbid obesity)			Prevalence of overweight and obesity		
				Boys (%)	Girls (%)	Total (%)	Boys (%)	Girls (%)	Total (%)	Boys (%)	Girls (%)	Total (%)
Nationally based data												
Whelton et al, 2006 [227]	2001-2002	14036	4-13	17%	21%	19%	6%	8%	7%	23%	29%	26%
O'Neill et al, 2007 [25]	2003-2004	596	5-12	15%	20%	17%	4%	9%	7%	19%	29%	24%
Layte & McCrory, 2011 [242]	2007-2008	8136	9.0-9.9	17%	22%	19%	5%	8%	7%	22%	30%	26%
Heavey et al, 2009 [222]	2008	2420	7.0-7.9	13%	19%	16%	5%	8%	7%	18%	27%	23%
Heinen et al, 2014 [223]	2010	1011	7.0-7.7	14%	20%	17%	4%	5%	4%	18%	24%	21%
Heinen et al, 2014 [223]	2012	1002	7.0-7.7	14%	17%	15%	3%	5%	4%	17%	22%	20%
Regionally based data												
McMaster et al, 2005 [243]	2001-2002	328	4.2-7.9	16%	18%	17%	9%	8%	9%	25%	26%	25%
Harrison et al, 2006 [232]	2003	312	9-11	27%	24%	26%	7%	9%	8%	34%	33%	34%
Evans et al, 2010 [244]	2004-2007	3493	6.0-6.9	17%	22%	19%	6%	9%	8%	23%	31%	27%
Barron et al, 2009 [245]	2007	969	4.5-13.5	18%	18%	18%	7%	7%	7%	24%	25%	25%
Murrin et al, 2012 [246]	2007-2008	529	5-7	19%	23%	21%	7%	8%	7%	25%	30%	28%
Belton et al, 2010 [248]	2008	301	6-9	14%	15%	15%	6%	6%	6%	20%	21%	21%
Fitzgerald, 2010 [249]	2008-2009	204	9-12.9	14%	24%	17%	9%	2%	5%	22%	26%	24%
HSE Meath, 2009 [226]	2009	1468	11-13	17%	20%	19%	4%	7%	6%	22%	28%	25%
Hollywood et al, 2012 [233]	2009	537	4-12	15%	23%	19%	12%	10%	11%	27%	33%	30%
CCLaS Study	2012-2013	1068	8-11	20%	21%	20%	4%	7%	5%	24%	28%	25%

#all prevalence estimates are rounded to the nearest whole number, as a result some numbers may appear not to add but this is due to rounding up or down of prevalence estimates, ^author of study contacted and asked to provide prevalence rates for overweight and obesity using IOTF definitions, ^^due to the complexity of the WHO European Childhood Obesity Surveillance programme data, only prevalence estimates from the 7 year olds is presented in this current review, *EK conducted the analysis to obtain prevalence estimates of overweight and obesity using IOTF definitions

4. DIET, PHYSICAL ACTIVITY, LIFESTYLE BEHAVIOURS AND PREVALENCE OF CHILDHOOD OBESITY IN IRISH CHILDREN: THE CORK CHILDREN'S LIFESTYLE STUDY (CCLAS) PROTOCOL (PAPER 2)

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THIS PAPER WAS PUBLISHED IN JMIR RESEARCH PROTOCOLS IN 2014 (PLEASE SEE APPENDIX 8)

4.1. Abstract

Background

Childhood obesity is complex and its aetiology is known to be multifaceted. The contribution of lifestyle behaviours including poor diet and physical inactivity to obesity remains unclear. Due to the current high prevalence, childhood obesity is an urgent public health priority requiring current and reliable data to further understand its aetiology.

Objective

The objective of this study is to explore the individual, family and environmental factors associated with childhood overweight and obesity, with a specific focus on diet and physical activity. A secondary objective of the study is to determine the average salt intake and distribution of BP in Irish children.

Methods

This cross-sectional survey (CCLaS Study) was conducted in children aged 8-11 years in primary schools in Cork, Ireland. Urban schools were selected using a probability proportionate to size (PPS) sampling strategy, and a complete sample of rural schools from one area in Cork County were invited to participate. Information collected included physical measurement data (anthropometric measurements, BP), early morning spot and 24 hour urine samples, a 3 day estimated food diary, and 7 days of accelerometer data. Principal (school head) reported, parent/guardian-reported, and child-reported questionnaires collected information on lifestyle behaviours and environmental attributes. The CCLaS Study was

designed by the Department of Epidemiology and Public Health in University College Cork, Ireland in 2011 and 2012. Piloting and modification of study methods was undertaken. Data collection took place between April 2012 and June 2013.

Results

Overall, 27/46 schools and 1075/1641 children of which 623 were boys participated.

Conclusions

The CCLaS Study has collected in-depth data on a wide range of individual, family, social, and environmental correlates which will allow us to access multilevel influences on childhood obesity. This study will contribute to the evidence base by highlighting current knowledge and gaps regarding the predominant drivers of childhood obesity.

4.2. Background

The CCLaS Study was designed by the Department of Epidemiology and Public Health in University College Cork in 2011 and 2012. I was the lead researcher of the CCLaS Study and was involved in the design, conduct and analysis of the study. The CCLaS Study is funded by the National Children's Research Centre, Crumlin, Dublin. The data from this study is presented in Chapters 3, 5 and 6.

4.2.1. Rationale for the Cork Children's Lifestyle (CCLaS) Study

Similar to estimates in other developed countries, one in four Irish children are overweight or obese [2, 242]. With the high prevalence and known adverse consequences of being obese [26, 61], childhood obesity remains an urgent public health priority requiring current and detailed data to further understand its aetiology and to inform public health policies and interventions [251, 252].

4.2.2. Framework for describing risk factors for childhood obesity in the CCLaS Study

Social-ecological theory suggests that factors at multiple levels of influence (individual, family, community and organizational factors) can enable or constrain health related behaviours and should be considered when researching the determinants of obesity [84]. There is increasing consensus that environmental and lifestyle factors rather than genetic or biological factors are the primary drivers of the current childhood obesity epidemic [75-78]. A number of likely determinants of obesity have been identified including poor diet, physical inactivity, sedentary behaviour, low socioeconomic status and the built neighbourhood environment [133, 241, 253-255]. Each of these risk factors has been described in Chapter 2.

There is a general perception that poor diet and physical inactivity are major contributors to the current obesity epidemic [1]. However, the relative contribution of poor diet and physical inactivity to childhood obesity are not well understood [81, 87, 256, 257]. For example, little is known about dietary behaviours including food choice [258] and salt intake in children [259]. High salt intake is associated with poor diet [260, 261], high BP [262] and increased energy intake in children [263]. However, the association between childhood obesity and salt remains understudied with some research indicating that salt may be indirectly associated with obesity through poor dietary choices including SSB intake [263]. This is of concern as dietary behaviours are established at an early age [264] and both obesity and BP track throughout one's life [265].

The complex interplay between lifestyle patterns and environmental factors further complicates uncovering pathways to obesity [70]. Studies containing in-depth data on the association between a broad range of lifestyle factors and multiple measures of weight status are sparse, particularly in the Republic of Ireland. A small number of Irish studies have assessed diet, physical activity or weight status in children but most have only collected data on either physical activity or diet. In addition, most have used self-reported measures of weight status or physical activity and little evidence is available on the wider environmental determinants of lifestyle patterns and obesity [131, 228, 248]. As the CCLaS Study collected in-depth data on diet, physical activity and weight status, this provides a unique opportunity to gain a deeper understanding on the multilevel influences associated with childhood obesity in Ireland.

The CCLaS Study aims to estimate the current prevalence of obesity in Irish children and to explore determinants of childhood obesity at an individual, family and environmental level with a specific focus on dietary patterns and physical activity. The secondary aim of the CCLaS Study is to estimate average salt intake and examine BP distribution in Irish children.

4.3. Methods

4.3.1. Aims and Objectives

The CCLaS Study aims to assess the current prevalence of overweight and obesity in Irish children and explore risk factors at an individual, family, and environmental level in a sample of children 8-11 years of age in primary schools in Cork, Ireland.

4.3.2. Primary Objectives

A primary objective is to assess the weight status and estimate the current prevalence of overweight and obesity using objectively measured height, weight, waist circumference and skinfold thickness measurements in Irish children 8-11 years of age.

The second primary objective is to explore individual, family, and environmental factors associated with childhood overweight and obesity with a specific focus on dietary patterns and objectively measured physical activity.

4.3.3. Secondary Objectives

A secondary objective is to assess the average salt intake and distribution of BP in children 8-11 years old in Ireland.

4.3.4. Study Population

The CCLaS Study is a cross-sectional survey conducted in Cork, Ireland. Cork is located in the South West of Ireland and Cork City has a population of 120,000. Mitchelstown is a rural area in Cork County with a population of >3000 and is located approximately 50 kilometres from Cork City. Information on primary schools in Cork City and Mitchelstown was obtained from the Department of Education and Skills website. The website contains information on school name, location, gender mix, size and disadvantaged status. Disadvantaged status is assigned to schools based on the socio-demographic and socio-economic profile of the families whose children attend the school [266]. At the national level, one in five primary schools has disadvantaged status. However, nearly half of Cork City schools have disadvantaged status, with approximately 40% of primary school children in Cork City attending a disadvantaged school [266].

Special needs schools and schools without age eligible children were excluded from the sampling frame. All other primary schools in Cork City and Mitchelstown were included in the sampling frame. At the time of sampling, there were 51 primary schools with approximately 13,230 students in Cork City which met the sampling frame criteria. All 5 primary schools in Mitchelstown (with approximately 800 students) met the sampling frame criteria [266]. Children in 3rd and 4th classes (years 5 of 6 of enrolment into primary school) were the target population, as the study wished to recruit children of a similar age to previously conducted Irish research [228].

4.3.5. Sampling Method and Sample Size

The study aimed to recruit 1000 participants in order to estimate the prevalence of overweight and obesity in Irish children with a precision of ±2.7% assuming a 26% prevalence rate of overweight and obesity within the study sample [229]. Allowing for a response rate of 70%, it was estimated that 1500 participants would need to be invited to partake in the study.

For the pre-pilot study, 2 city schools were recruited using convenience sampling. For the pilot and main study, a PPS sampling strategy was used to select a random sample of primary schools in Cork City. The PPS sample of city schools was based on school size. A small school was defined as having <100 pupils, a medium school having 100-300 pupils and a large school having >300 pupils. A complete sample of schools in Mitchelstown was invited to participate in the study. In order to achieve the sample size requirements, the schools not willing to participate in Cork City were replaced using a further purposive sampling strategy. The schools not willing to participate were replaced to represent the sampling frame population for (1) school disadvantaged status and (2) gender. As the recruitment of schools was undertaken over two consecutive school years, schools were sampled without replacement. All children in 3rd and 4th classes of participating primary schools were invited to participate in the study. Figure 4 shows a summary of the sampling and recruitment process.

4.3.6. School and Participant Recruitment

The principals (school heads) of selected schools were sent an invitation letter, an information sheet and a presentation containing study details. The principals were then contacted by telephone to arrange a face-to-face appointment with a study researcher to discuss the study. During the study meeting with the principal, the study aims, proposed methods and study procedures were discussed. With the principals' permission, the research team introduced the study to the 3rd and 4th class children of participating schools and a parent/guardian information letter and consent form was given to each child to bring home. The children were advised to discuss the study with their parents/guardians and to return the consent form to the school if they and their parents/guardians were willing to participate. The parent/guardian consent form was divided into 3 sections. The first section gave permission for the study child to participate in the study. The second section gave permission for a urine sample to be provided by the study child and the third section gave permission for the urine sample to be stored by long term freezing.

4.3.7. Data Collection Methods

4.3.8. Testing/Piloting

Prior to the main study, a pre-pilot study was conducted in two Cork City primary schools in April-May 2012 and a pilot study was conducted in 3 Cork City primary schools in May-June 2012. Overall, one hundred and forty children from 2 mixed gender schools, two boys' schools and one girls' school were recruited to participate in the pre-pilot and pilot studies. The study piloting aimed to test practical research issues including the timing of procedures. The study methods and study documents including the food diary and questionnaires were also tested and assessed during piloting. Study documents, the study protocol and SOP were amended where necessary.

4.3.9. Schools and Classroom Procedures

The study researchers were advised to strictly adhere to the methods outlined in the study protocol and SOP during the fieldwork process. Within the classroom, each child was provided with a study pack which contained: (1) a child questionnaire, (2) a parent/guardian questionnaire, (3) a 3 day estimated food diary, (4) an accelerometer and instructions and (5) a urine collection cup and instructions (where parent/guardian consent was granted). The research assistants were present for all classroom procedures and offered support and assistance where necessary. The children completed a self-reported questionnaire within the classroom, which was checked for completeness while on site. The accelerometers were described and placed on the non-dominant wrist of each child. The 3 day estimated food diary was explained using a poster template of the food diary. The researchers explained how to fill in the food diary and with assistance, that morning's breakfast was completed by the children within the classroom. The children were informed how and what day to provide the urine sample which was to be returned to the school once complete. The children were also instructed to return the parent/guardian questionnaire to the school once complete. A "pictogram" poster was placed in the classroom to remind children of the of study details they needed to recall.

4.3.10. Questionnaire Data

Table 4 outlines the individual, family and environmental factors measured in each questionnaire (see http://www.researchprotocols.org/2014/3/e44/ for questionnaires). The questionnaires were developed based on previously tested and validated questions with modification of some questions for the purposes of this study. Details of each questionnaire are described below.

4.3.11. Principal Questionnaire

The principal of each participating school was asked to complete a questionnaire which included questions under 6 main headings: (1) demographics, (2) health curriculum, (3) school policy environment, (4) level of nutritional care, (5) provision of physical activity and (6) parental/community support. This questionnaire has been used previously in a cross-sectional study in schools in Cork City [267].

4.3.12. Child Questionnaire

The child questionnaire was developed using questions from the following sources: (1) Sport, Physical Activity and Eating Behaviour: Environmental Determinants in Young People study [257], (2) GUI Study [228], (3) Growing Up in Australia: The Longitudinal Study of Australian Children (LSAC) [268], (4) Child Heart and Health Study in England [269] and (5) Physical Activity for Older Children Questionnaire [270].

The child-reported questionnaire contained questions under 5 major headings: (1) background information, (2) your neighbourhood, (3) food and diet, (4) sports and physical activity and (5) hobbies and activities.

4.3.13. Parent/Guardian Questionnaire

The parent/guardian questionnaire was developed using questions from a number of sources: (1) GUI Study [228], (2) Survey of Lifestyle, Attitudes, and Nutrition in Ireland [271], (3) Avon Longitudinal Study of Parents and Children [272], (4) LSAC study [268], (5) National Survey of Children's Dental Health [273], (6) Eating Among Teens Survey 1 [274], (7) Mitchelstown Cohort study [275], (8) Irish Census [276], (9) Child Feeding Questionnaire [277], (10) short version (self-administered) of the

International Physical Activity Questionnaire and [278] (11) Warwick-Edinburgh Mental Well-being Scale [279].

The parent/guardian reported questionnaire contained questions under 9 major headings: (1) study child's birth factors, (2) study child's current health, (3) study child's exercise and physical activity, (4) study child's hobbies and activities, (5) study child's diet and dietary habits, (6) current parental health, (7) parental diet, (8) general family eating questions and (9) family background.

4.3.14. Dietary Intake

Dietary intake was assessed using a consecutive 3 day estimated food diary which was developed for the purposes of this study (see http://www.researchprotocols.org/2014/3/e44/ for template of food diary). Instructions to complete the food diary, including food atlas photographs [280] to aid portion size estimation, were located at the beginning of the food diary. Each day in the food diary was broken into six meal sections. Each meal section had a pre-assigned title: (1) breakfast, (2) morning snack, (3) lunch, (4) afternoon snack, (5) dinner and (6) evening snack. There were six key questions to answer within each meal section: (1) time meal/snack was consumed, (2) location meal was consumed, (3) type of food or drink consumed, (4) quantity of food or drink consumed, (5) quantity leftover and (6) cooking method used. The food diary was explained to the children in the classroom setting. Firstly, the layout of the food diary was explained. Using a poster template, the children were then shown how to fill in each meal section. The children were also shown how to use the food atlas photographs at the beginning of their food diary to help estimate portion size.

Once the food diary was explained in the classroom the children were asked to fill in what they had for breakfast that morning. A member of the research team spent some time with each child to ensure that they understood what was involved. The children were advised to seek help from parents and teachers when filling in their food diary where possible. Detailed debriefing with the children occurred after the 3 day period using a prompt sheet and food atlas [280] in order to ensure completeness. Additional information was sought from the children where food or drink items were not recorded in detail. Food diary data was entered into netWISP version 4 (Tinuviel Software, Anglesey, UK). Output measures available from netWISP include nutrient intake, individual food intake and food group intake.

4.3.15. Physical Activity

Free living physical activity was measured over a consecutive 7 day period using a validated tri-axial Geneactiv accelerometer [281, 282]. The Geneactiv accelerometer is a small, lightweight, waterproof device [283]. The manufacturer (Activinsights Limited) calibrated the units prior to the study commencing. The accelerometers were set to record data at 100Hz for 7 days using the "on button press" setting on the Geneactiv software version 2.2. The children were asked to wear the accelerometer all day and night over the 7 day period. They were informed only to remove the accelerometer for sports if their coach suggested it was necessary. The accelerometers were fitted on the wrist of the non-dominant hand and information on handedness was recorded by the research assistants. The accelerometers were downloaded in ".csv" and ".bin" format and saved on hard drives. The data was collapsed into 1 second and 1 minute epochs for data analysis. Output measures available include minutes spent sedentary and at low, moderate and vigorous activity. The classification thresholds for activity intensity were defined using those outlined by Phillips et al, 2012 which were designed specifically for the GENEA accelerometer.

4.3.16. Anthropometric and Blood Pressure Measurements

The anthropometric and BP measurements were taken by fully trained researchers using standard procedures. The researchers received training from an experienced research nurse and dietician prior to the study commencing. Retraining sessions occurred during the data collection period to ensure standard procedures were being employed during measurements. The data was also checked for measurement variability during the data collection period. The study equipment was calibrated prior to data collection and monthly thereafter.

A summary of the anthropometric and BP measurements methods is described in Table 5. All measurements were taken in a sensitive manner in a private room or behind screens in each primary school. There were two children and at least two research assistants that remained in the room at all times. For the waist circumference and skinfold thickness measurements where two readings were taken, the mean value is to be used for analysis. The children were classified as normal weight, overweight or obese using age and gender specific IOTF definitions [27]. Mean systolic and diastolic BP was calculated using the average of readings two and three.

4.3.17. Urine Samples

Only children whose parents provided consent for urine collection were provided with a urine collection cup and instructions. The children were asked to provide an early morning spot urine sample on a specified day which corresponded to a food diary completion day. Where principals were agreeable, a subsample of children were asked to provide a 24 hour urine sample (n=100) on a weekend day, which corresponded to a food diary completion day. There were sixteen children from one of the pre-pilot schools that were asked to provide an early morning spot and 24 hour sample. The 24 hour samples provide an indication of average urine volume produced in a 24 hour period by the children. Osmolality testing was carried out on the 24 urine samples to determine urine concentration using a Micro-Osmometer Model 3300 in Cork University Hospital, Cork, Ireland. The hydration status of the children with 24 hour samples will be determined from the osmolality derived urine concentrations. All samples were analysed for sodium, potassium, urea, and creatinine in the Biochemistry Department in the Mercy University Hospital, Cork, Ireland (Accredited Laboratory ISO-15189). All electrolytes were analysed using the Abbott Architect c8000 (Abbott Laboratories). The methodology for sodium and potassium measurement used ion-selective electrodes, urea analysis was based on an enzymatic assay using urease and creatinine was analysed using the kinetic alkaline picrate method. Where consent was provided, a 2 ml aliquot urine sample was frozen in a secure, password protected freezer.

4.3.18. Ethics and Ethical Issues

Ethical approval for the CCLaS Study was obtained from the Clinical Research Ethics committee of the Cork Teaching Hospitals, Cork, Ireland. Only children with parent/guardian informed consent participated in the study and parents/guardians were free to withdraw their children from the study at any point. Feedback on the physical measurements was provided to all parents of participating children in the form of a letter. The parents of children with high BP or morbid obesity were advised to consult their general practitioner and a general practitioner letter was enclosed with the feedback. A consultant paediatrician and a consultant in general internal medicine and nephrology from the Mercy University Hospital, Cork, Ireland provided advice on any high or unusual readings prior to feedback being provided to parents.

4.3.19. Data Processing and Quality Assurance

Comprehensive data cleaning was undertaken. First, all data were checked for outliers. Ten percent (108/1075) of the data was then randomly selected and re-checked for errors. Out of the 39,999 questionnaire data points checked, 139 errors were found and corrected. An error rate was then calculated (0.35% for questionnaire data). Missing data will be accounted for during data analysis either by data imputation or by creating missing data categories if possible. A standardised codebook will be generated to ensure standard definitions and cut off points are used during analysis.

4.3.20. Analysis Plan

The data will be analysed using the statistical software package Stata 12 (StataCorp LP). All necessary statistical assumptions will be tested prior to data analysis. Basic descriptive statistics will be used to describe the study population and will provide prevalence estimates of overweight and obesity. Basic descriptive statistics will also be used to explore BP distribution. Descriptive findings will be stratified by gender. Crude and adjusted multivariate analysis will be conducted to assess the association between outcome variables and possible determinants.

4.4. Results

Data collection was undertaken between April 2012 and June 2013.

4.5. Discussion

4.5.1. Lessons Learned During the Pilot Studies

The pilot studies provided valuable insight into a number of practical and methodological issues. The practical and operational issues encountered included timing, obtaining an adequate response rate and increasing awareness of the study in the local community. Obtaining a principal's consent for a school to take part in the study took longer than anticipated, especially when teachers, board of management committees and parent associations were consulted. In the main study, greater lengths of time were allowed when approaching schools to participate in the study. A relatively low response rate from parents and children was obtained during the piloting phase of the study. A possible explanation for this is that the piloting phase of the study was undertaken close to the summer holidays. However, for the main study a number of methods were used to encourage a greater response rate. The children were given a longer period of time to return the consent forms, a study logo was designed and researchers wore study t-shirts with the logo when introducing the study in order to be more child friendly. Numerous phases of promotion of the study were also undertaken, with articles being written in local newspapers and letters being sent to local health and community organizations promoting the study. Study posters were also placed in shops and businesses throughout Cork City and Mitchelstown.

Methodological issues were also encountered, especially in terms of study document design. The original consent form was too complicated and as a result was not being completed correctly by parents. In some cases it was difficult to decide if a parent was providing consent or not. Therefore, the consent form was made clearer and easier to complete. The parent questionnaire appeared to be too long and this may have acted as a disincentive for parents to complete later sections in the questionnaire. For the main study, a number of questions were removed and the questions of utmost importance were located at the start of the questionnaire. On the cover page of the questionnaire, parents were informed of the aim of the questionnaire and of the anticipated length of time needed to complete all of the questions. The food diary used in the pilot study was too complicated for children 8-11 years old to understand and fill in completely. As a result, this made the debrief process difficult. The food diary was made more child-friendly by changing the layout, reducing the number of questions asked about each meal and by including a number of photographs from the food atlas at the beginning of the food diary to aid portion size estimation.

4.5.2. Recruitment Issues

Recruitment from schools is a difficult, multilevel process involving principals, teachers, parents and their children [284]. Some research suggests that recruiting schools to participate in studies is becoming increasingly difficult, with non-response within schools becoming increasingly evident [285-287]. The CCLaS Study aimed to collect data from a predominantly urban location (Cork City) and from one rural location (Mitchelstown). It was intended that an equal proportion of girls and boys would be recruited and that the proportion of children attending disadvantaged versus non-disadvantaged schools would represent the sampling frame. During the study, recruitment of schools proved difficult and further purposive sampling was necessary to achieve sample size requirements. A greater proportion of boys participated and this is likely due to the nature of the study methods used. Boy's only schools appeared to be more interested than girls only schools in the physical activity and accelerometer aspects of the study and were interested to participate for this reason. On the contrary, the principals of non-participating girls only schools appeared more concerned about the anthropometric aspect of the study and some principals expressed concerns over the sensitivity and possible long-term implications of measuring children.

Disadvantaged schools were more difficult to recruit than non-disadvantaged schools. Some school principals expressed concerns over the study methods, especially regarding children providing a urine sample. There were three principals from disadvantaged schools that agreed to take part in the study only on the condition that urine samples were not collected from the children in their school. School principals reported a variety of other reasons for not partaking. These include the low literacy of parents whose children attend the school, parents being suspicious of the study or study methods, the school being too busy and other schools gave an outright “no” with no explanation for nonparticipation. Research fatigue in Cork City schools was also evident, with a number of non-participating schools reporting they had just taken part in a different study or found studies overly time consuming. The proximity of city schools to local research institutions is a likely explanation for research fatigue and thus further school based studies require carefully designed recruitment strategies.

<u>4.5.3. Strengths</u>

The sample size is relatively large and represents 1075 children out of approximately 3350 eligible children in the overall sampling frame. A predominant strength of this study is the depth of data on lifestyle, diet and physical activity data collected at an individual, family, and school level which will allow for in-depth exploration on the potential determinants of childhood overweight and obesity. This is one of the first studies in Europe designed to collect such data. A number of objective anthropometric measurements were taken to describe weight status. The study collected objectively measured physical activity data in free living conditions over a 7 day period. The corresponding physical activity questionnaire data will provide valuable some information of the context of physical activity behaviours and patterns. Seasonality will be accounted for as the data was collected throughout the school year (October-June). The thoroughly debriefed 3 day estimated food diaries provide comprehensive data on dietary intake patterns and behaviours. This is the first study, to our knowledge, in Ireland to provide objective estimates of salt intake from spot and 24 hour urine samples and to assess the distribution of BP in a large sample of Irish children.

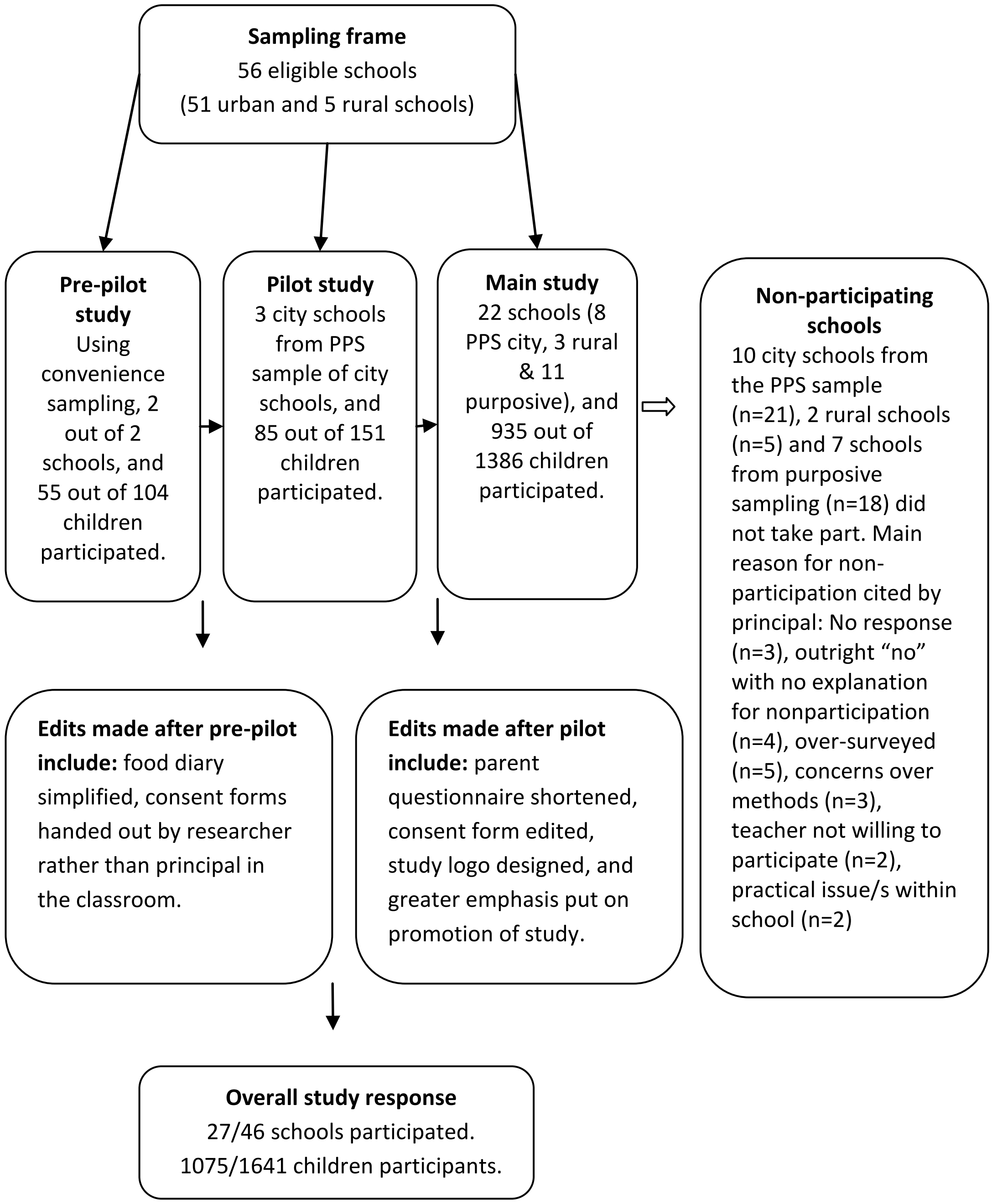
4.5.4. Limitations

There are a number of limitations to the study. A relatively low response rate was obtained from the original sample of city schools though the desired sample size was achieved using purposive sampling. However, some response bias may have been introduced into the study. Information on non-responding children is not available. As the food dairies are self-reported, some misreporting and non-reporting may have occurred. However, the food diaries were thoroughly debriefed by a trained researcher, though this may have resulted in some reporting bias of dietary intake. A 3 day food diary may not be representative of habitual dietary intake. Some response bias may have been introduced into the child questionnaire responses as they were completed in a classroom setting though children were encouraged to complete the questionnaires independently.

4.5.5. Conclusions

This study aims to estimate the current prevalence of overweight and obesity in 8-11 year old Irish children. The research from the CCLaS Study will explore the individual, family and environmental correlates of childhood obesity. To date, there are no reliable data on the average salt intake or distribution of BP in Irish children. Valuable comparisons with findings at an Irish, European, and International level will be made. In particular, CCLaS Study findings will be compared to results from the GUI Study, which is a national longitudinal study of children in the Republic of Ireland. The CCLaS Study aims to highlight the modifiable social, economic, and cultural dimensions of childhood obesity. It is anticipated that this will highlight areas of action for policymakers, planners and developers with a responsibility for addressing childhood obesity and creating sustainable healthy environments.

Figure 4. Flowchart of sampling and recruitment of schools and children in the CCLaS Study



Footnote: PPS=probability proportionate to size

Table 4. Individual, family and environmental factors measured by the CCLaS questionnaires

	Child questionnaire	Parent/guardian questionnaire	Principal questionnaire
Individual factors			
Demo-graphics	Gender, age	Gender and age of parent respondent, relationship of parent respondent to study child	Principal gender, school gender mix, school size, school disadvantaged status
Birth factors		Birth weight, gestational age, mode of delivery, breastfeeding	
Diet	Breakfast consumption, salt use at table, favourite snack and drink, frequency of consumption of favourite snack and drink	Type and quantity of milk consumed, type of spread typically used, consumption of breakfast, evening meals, fruit and vegetables, quantity of intake of soft drinks and sports drinks, supplement use, special dietary requirements, parental beliefs, attitudes and practices to child feeding	
Physical activity	Types and frequency of activities including physical activity during and outside school hours	Frequency of light and hard activity, mode of transport to and from school	
Sedentary behaviours	Frequency of use of computer games, games consoles, TV, time spent at homework	Amount of time spent watching TV, reading, playing computer games, games consoles and doing homework	
Health/ lifestyle	Perception current health and weight status, favourite hobby, pet ownership	Current health status, description of ongoing health issues, perception of child weight, child sleeping patterns	
Family factors			
Socio-demographic / family environment	Siblings	Parent reported variables on self and family*: Number of residents in family home, age and relationship of each resident to study child, ethnicity, marital status of parent respondent, car ownership, childcare arrangements, parent and partner (if applicable) education and occupation	

	Child questionnaire	**Parent/guardian questionnaire**	**Principal questionnaire**
Parental factors		Parent reported variables on self[A]: Frequency of consumption of fried foods, fruits, vegetables and salt, snacking patterns, frequency and amount of physical activity, perceived current health status and types of health conditions, perception of current weight status, dieting frequency, self-reported height and weight (and of partner where applicable), current smoking, alcohol use and well-being status	
Family food and eating environment		Parent reported variables on family[*]: Frequency and type of eating out, frequency of ordering takeaway food, frequency of eating family meals together, affordability of food	
Environmental factors			
	Playground located in neighbourhood, safe play areas in neighbourhood , garden present at family home, perceived safety of neighbourhood		Provision of food and nutrition education, school health policy available, involvement in and types of health promotion activities, access to and availability of healthy/unhealthy foods in school, provision of school breakfasts and/or lunches, involvement in and types of school sports teams and after school activities, parent involvement in school

Footnote: [*] Parent/guardian reported data on child unless specified otherwise

Table 5. Summary of study methods used in the CCLaS Study

Measure	Number of measures	Device	Method
Height	1	Leicester portable height stick	Measured to the nearest mm without shoes
Weight	1	Tanita WB100MA mechanic scales	Measured to the nearest 0.1kg without shoes and in light clothing
Waist circumference	2	Non-stretch tape Seca 200 measuring tape	Measured to the nearest mm and located at the midpoint between the child's lower rib margin line and the iliac crest
Skinfold thickness (triceps)	2	Holtain Tanner/ Whitehouse skinfold calipers	Measured at the right hand side of the body to the last complete mm. The triceps was located on the posterior midline of the upper arm, over the triceps muscle, halfway between the acrosion process and olecranon process. The elbow was extended and relaxed for the measures
Skinfold thickness (subscapular)	2	Holtain Tanner/ Whitehouse skinfold calipers	Measured at the right hand side of the body to the last complete mm. The subscapular was located on the diagonal line coming from the vertebral border to between 1 and 2cm from the inferior angle of the scapulae
Mid upper arm circumference	1	Non-stretch tape	Measured using a non-stretch tape to the nearest mm from the right arm whilst relaxed. The mid-point was located half ways between the top of the shoulder and the tip if the elbow
BP	3	Omron M6	BP was measured from the right arm using a validated automatic oscillometric device [288, 289]. The mid upper arm circumference determined cuff size. The cuff was placed approximately 2cm above the crease of the elbow. The child was seated comfortably for at least 5 minutes prior to the first reading. BP was measured three times with one minute between each measurement. Children were asked to remain quiet and to sit still while each reading was being taken. Systolic BP, diastolic BP and pulse were recorded

Measure	Number of measures	Device	Method
Accelerometer	7 consecutive days	Geneactiv	Accelerometer set to record data at 100Hz and were worn on non-dominant hand for 7 days
Estimated food diary	3 consecutive days		Children recorded everything they ate and drank for 3 days. Food diaries were fully de-briefed by a trained researcher after the 3 day period
Early morning spot urine sample	1		Children were asked to provide an early morning spot sample a day which corresponded to a food diary completion day
24 hour urine sample	1		A subsample of children were asked to provide a 24 hour urine sample on a weekend day which corresponded to a food diary completion day

6. THE EFFECTS OF INDIVIDUAL, FAMILY AND ENVIRONMENTAL FACTORS ON PHYSICAL ACTIVITY LEVELS IN CHILDREN: A CROSS-SECTIONAL STUDY (PAPER 4)

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THIS PAPER WAS PUBLISHED IN BMC PEDIATRICS IN 2014 (PLEASE SEE APPENDIX 8)

6.1. Abstract

Background

Physical activity plays an important role in optimising physical and mental health during childhood, adolescence, and throughout adult life. This study aims to identify individual, family and environmental factors that determine physical activity levels in a population sample of children in Ireland.

Methods

Cross-sectional analysis of the first wave of the nationally representative GUI study. A two-stage clustered sampling method was used where national schools served as the primary sampling unit (response rate: 82%) and age eligible children from participating schools were the secondary units (response rate: 57%). Parent reported child physical activity levels and potential covariates (parent and child reported) include favourite hobby, total screen time (TST), sports participation and child BMI (measured by trained researcher). Univariate and multivariate multinomial logistic regression (forward block entry) examined the association between individual, family and environmental level factors and physical activity levels.

Results

The children (N = 8,568) were classified as achieving low (25%), moderate (20%) or high (55%) physical activity levels. In the fully adjusted model, male gender (OR 1.64 [95% CI: 1.34-2.01]), having an active favourite hobby (OR 1.65 [95% CI: 1.31-2.08])

and membership of sports or fitness team (OR 1.90 [95% CI: 1.48-2.45]) were significantly associated with being in the high physical activity group. Exceeding two hours TST (OR 0.66 [95% CI: 0.52-0.85]), being overweight (OR 0.41 [95%CI: 0.27-0.61]; or obese (OR 0.68 [95%CI: 0.54-0.86]) were significantly associated with decreased odds of being in the high physical activity group.

Conclusions

Individual level factors appear to predict physical activity levels when considered in multiple domains. Future research should aim to use more robust objective measures to explore the usefulness of the interconnect that exists across these domains. In particular how the family and environmental settings could be useful facilitators for consistent individual level factors such as sports participation.

6.2. Background

Physical activity plays a fundamental role in maintaining and improving physical and mental health, both during childhood and in later years [326, 327]. Participating in high levels of physical activity during childhood produces immediate and, long-term health benefits in adulthood [328, 329]. Despite the known health benefits, physical activity levels decline across the lifespan, particularly during adolescence [328, 330-332]. Identified as the fourth leading risk factor for global mortality [333], physical inactivity is a major public health concern worldwide, associated with an estimated one million deaths annually in the WHO European region alone [118].

WHO guidelines recommend that children participate in at least 60 minutes of MVPA daily [334]. Worldwide, research has indicated that children are not achieving these guidelines, with estimates of activity levels varying both between and within countries (see Chapter 2 for more details) [130, 257, 335-337]. For example, 42% of children aged six to 11 years in the USA participate in 60 minutes of MVPA daily [337]. Similarly, in the UK, objectively measured physical activity measurements indicate that just 51% of four to 10 year olds (33% of four to 15 year olds) meet the recommended guidelines [335]. In comparison, 19% of primary school children and 14% of 10 to 18 year olds in Ireland meet the recommendations [130].

Achieving the recommended levels of physical activity per day is essential for the prevention and treatment of many health problems such as obesity (see Chapter 2 and 7 for more details). In particular, with evidence of levels of physical activity tracking from childhood through adolescence and into adulthood [328], developing an active lifestyle from a young age may also produce long term benefits. However, to design effective strategies for increasing children's physical activity levels, effects on, and determinants of, activity levels need to be well understood.

In order to structure relevant determinants, a social ecological framework for this research was adopted. Social ecological theory proposes that a child's development is affected by multiple levels of influencers including direct influencers such as family, school and neighbourhood factors [338, 339]. Bronfenbrenner's ecological model advocates the need to address factors at multiple levels in order to understand and change physical activity behaviours [339]. Multilevel approaches derived from such ecological models have been recommended to examine physical activity determinants [340].

Existing evidence on correlates of physical activity in children have been reviewed extensively in the literature [332, 341]. However, despite the awareness of multilevel associations, many of these factors have been investigated individually. Further, in 2009, the top five future research priorities for understanding and eliminating disparities in obesity, diet, and physical activity were published following a meeting of experts in the USA [342]. One key recommendation for physical activity research was to use methods to study individual and environmental factors simultaneously [342]. This research uses nationally representative data to examine the multilevel predictive capability of these correlates, specifically; the individual, family, and environmental level factors of physical activity among nine year olds in Ireland. The first aim of this study is to identify the distribution of individual, family and environmental factors by physical activity levels. A further novel objective is to model the multilevel effects of these factors on the physical activity levels of children at age nine.

6.3. Methods

6.3.1. Study design and sample

The sample comprised of 8,568 nine year old children participating in the first wave (2007/2008) of GUI Study [228]. The GUI Study is a nationally representative cohort of nine year old children living in the Republic of Ireland. Eligibility criteria included children who were born between 1st November 1997 and 31st October 1998. The sample was selected using a two-stage clustered sampling method within the Irish primary school system (all mainstream, special and private schools), whereby the school was the primary sampling unit and the age eligible children attending the school were the secondary units [343, 344]. In the first stage, 1,105 schools from the national total of 3,200 were randomly selected using PPS sampling, followed by recruitment of a random sample of eligible children within each school (stage two).

At the school level, a response rate of 82.3% (910 schools) was achieved, while at the level of the household (i.e. eligible child) 57% of children and their parent/guardians participated in the study.

Fieldwork for the school-based component was carried out between March-November 2007, while fieldwork for the home-based phase of data collection ran from July 2007-July 2008. The data were weighted prior to analysis to account for the complex sampling design, which involved the structural adjustment of the sample to the population using Census of Population statistics while maintaining the case base of 8,568 children [344].

Ethical approval was granted by the Health Research Board's Research Ethics Committee based in Dublin, Ireland. Written informed consent was also obtained from a parent or guardian and the study child prior to commencement of the data collection process [344].

6.3.2. Data collection procedures

Trained social interviewers conducted interviews with the study child and their parents/guardians within the home. Parents nominated a primary caregiver (the parent who spent most time with the study child) who was the primary respondent.

In 98% of cases, this was the study child's biological mother. The primary caregiver is referred as the parent throughout this chapter. The main interviews were completed on a Computer Assisted Personal Interview basis. There was also a self-complete paper based supplement for all respondents, which included some potentially sensitive questions such as issues about the marital relationship, marital conflict, experience of depression, and use of drugs [344]. Sources and validity of each of the questions used for the GUI study are contained elsewhere [344]. Anthropometric measurements for the parents as well as the study child were also taken during the household interview using standard procedures [344].

6.3.3. Dependent variable

Child physical activity levels were calculated using data reported by the study child's parent. The physical activity questions included in the parent's questionnaire were adapted from the Leisure Time Exercise Questionnaire [345]. The parent reported *the number of days out of the previous 14 that the child had engaged in 'hard' exercise for at least 20 minutes*. Hard exercise was defined as exercise that resulted in heavy breathing and a fast heart beat [343]. This self-report measure has been shown to demonstrate concurrent validity with measures of maximum oxygen intake (VO2 max) and muscular endurance [346], as well as acceptable test-retest reliability [347].

Study child's physical activity was re-coded into a three level variable based on previous research [348]: low "0-4 days", moderate "5-8 days" and high ">9 days" physical activity groups. Nine or more days out of previous 14 was the highest possible value and corresponds closest to the recommended physical activity guidelines. This is also consistent with other Irish research using the same wave of the GUI data [153].

6.3.4. Covariates

6.3.5. Child reported physical activity

The study children were asked to report how often they take exercise each week. The variable is coded as never, 1-2 times per week, 3-4 times per week, almost every day. This variable is described in the descriptive analyses.

6.3.6. Individual level variables

Five individual level variables were included: the study child's gender, whether the study child was a member of a sports or fitness club (yes/no), TST (<2 hours TST per day/>2 hours TST per day), the nature of study child's favourite hobby (active/inactive) and the study child's weight status (normal/overweight/obese). Data for the former three variables was parent reported. The study child's favourite hobby variable was based on child reported data. Weight status was classified using objectivity measured data.

TST was categorised based on the recommendations of the American Academy of Paediatricians [141]. This variable was created by combining three screen time variables; hours spent watching TV/videos, playing video games and using a computer (<1 hour, 1-3hours, >3 hours). This resulted in a seven level response variable, classified as: "adhering to (<) the recommended maximum two hours/day" or "exceeding the recommended two hours/day". Adhering to the recommended TST was defined as the study child only exceeding one hour of screen time in one of the screen time variables (giving a potential for maximum two hours TST).

The study child's favourite hobby variable was created using 32 hobbies listed by the child, classified into a two level response "active" or "inactive" (16 hobbies in each group). A hobby was considered active if it required the child having a physically active participatory role and inactive if the child had a permissive role or remained sedentary. Active hobbies included: basketball, football, hockey and gymnastics. Inactive hobbies included: reading, listening to music and watching TV.

Trained interviewers were responsible for height and weight measurements of each study child and each adult respondent. Height data was recorded to the nearest millimetre using a Leicester portable height stick [344]. Weight was recorded using a SECA 761 flat mechanic scales to the nearest 0.5 kilogram [344]. Child BMI was classified as normal weight, overweight (BMI of 19.46 for boys and 19.45 for girls) or obese (BMI of 23.39 for boys and 23.46 for girls) using age (9.5 years) and gender specific IOTF definitions [30].

6.3.7. Family level variables

Six family level variables were included: parent's education (third level/post-secondary/ higher secondary/lower secondary or less), employment status (in full time work/not in full time work), parenting style (authoritative/permissive) parent weight status (normal, overweight or obese), whether the child has siblings (yes/no) and the household structure (single parent/two parent). These variables were based on parent reported data with the exception of objectively measured weight status.

The parenting style variable described the practices of the child's parent. For the purpose of this research, the original responses; authoritarian, authoritative, permissive and uninvolved parenting styles were re-coded as "authoritative" or "permissive". The parent's measured BMI data was classified according to WHO guidelines as normal weight (<25 kg/m^2), overweight (≥25 and <30 kg/m^2) or obese (≥30 kg/m^2) [1].

6.3.8. Environmental level variables

Five environmental level variables were included: transport to and from school (active both ways/active one way/inactive both ways), school playground (good or excellent/fair or poor), school sports facilities (good or excellent/fair or poor), after school activities (agree/disagree) and safe play areas in neighbourhood (agree/disagree).

The school transport variable (parent reported) was created using questions on how the study child travelled both to and from school (walks, by public transport, school bus/coach, car, cycles or other). Responses were combined and re-coded as "active both ways", "active one way, inactive one way" and "inactive both ways".

The school playground and sports facilities data were obtained from the school principal questionnaire while data on neighbourhood facilities were parent reported. Responses for school facilities were re-coded as "very good/excellent" or "fair/poor". Responses to both neighbourhood facilities were re-coded as "agree" or "disagree".

6.3.9. Statistical analysis

Secondary analysis was performed using Stata (v12, intercooled). P-values less than 0.05 were considered statistically significant. Probability weights were applied to the data using survey data commands to account for the complex survey design.

Missing data levels were very low for the majority of the variables used, and where missing values were identified (e.g. 5.2% of parent BMI measurements) it was found not to be missing at random and hence, data could not be imputed. Parent reported physical activity data was available for 99.9% of the study children, giving an effective case base of 8,566 children for analysis.

Descriptive statistics were performed to evaluate the children's physical activity related characteristics. Unadjusted multinomial logistic regression methods were used to measure the association between independent predictor variables and moderate/high physical activity levels. Multinomial multivariate logistic regression was conducted to assess their predictive capability (adjusting for all potential confounders) using the forward block entry function: individual, family and environmental blocks. The first block (model one) included the five individual level factors: gender, weight status, TST, favourite hobby and being a member of a sports or fitness team. Block two (model 2) included the six family level factors: parent's education, parent's employment status, parent's weight status, siblings, parenting style and household structure. Block three (model 3) contained the five environmental level factors: transport to and from school, school's playground facilities, school sports facilities, safe neighbourhood to play in and after school activities.

6.4. Results

6.4.1. Overview of children's physical activity patterns

Children were categorised into three physical activity groups: low (N =2,135), moderate (N =1,740) and high (N =4,691). Overall, 26.3% (95% CI, 24.9-27.7) had low, 19.3% (95% CI, 18.2-20.5) had moderate and 54.4% (95% CI, 52.8-55.9) had high physical activity levels. Gender differences existed, with 61% (N =2,609) of boys categorised as being highly active (high physical activity group) compared to 48% (N =2,082) of girls ($p < 0.001$). Physical activity /obesity related demographics stratified by gender are presented in Table 14. Over half of the children (N =4,730) reported taking exercise almost every day (55% of boys vs. 45% of girls, $p < 0.001$), of which 65% (N =3,123) were in the high, 16% (N = 94) in the moderate and 19% (N =813) in the low physical activity groups ($p < 0.001$). According to child reported data, 25% (N =2,136) of children met the WHO guidelines of participating in 60 minutes of MVPA each day. Boys were more likely to achieve the recommended guideline than girls (29% versus 21%, $p < 0.001$). Valid height and weight measurements for the study child were also obtained for 94.5% (N =8,136) of the sample. The estimated proportion of children in the normal, overweight, and obese categories was 74.1% (95% CI, 72.8-75.3), 19.3% (95% CI, 18.2-20.5) and 6.6% (95% CI, 5.9-7.4), respectively.

Table 15 presents the results of the univariate multinomial logistic regression. All five of the individual level factors were found to be associated with high physical activity while four were found to be associated with moderate physical activity levels. Of the family level factors, parent's education, parent's employment status, household structure and parenting style were significantly associated with moderate physical activity levels, while having siblings and parent's weight status were not. Method of travel to school level was not associated with either moderate or high physical activity levels, while, both safe playgrounds and participating in after school activities in the children's neighbourhood were found to be associated with both moderate and high physical activity.

6.4.2. Model one (individual level factors)

Of the individual level factors, male gender ($p < 0.001$), having a physically active favourite hobby ($p < 0.001$) and being a member of a sports or fitness group ($p < 0.001$) were positively associated with high physical activity levels (Table 16). Being a member of a sports or fitness team ($p < 0.001$) was positively associated with moderate physical activity. Being overweight or obese was negatively associated with both moderate and high physical activity, while exceeding the recommended maximum TST was negatively associated with high physical activity ($p < 0.001$). Obese children were 60% and 42% less likely to be in the high and moderate physical activity groups, respectively (OR, 0.40 [95% CI, 0.31-0.52] $p < 0.001$; OR: 0.58 [95% CI: 0.42-0.79] $p < 0.001$) compared to normal weight children. Overweight children were 21% and 23% less likely to be in the moderate and high physical activity groups, respectively (OR, 0.79 [95% CI: 0.65-0.97] $p = 0.02$; OR: 0.77 [95% CI, 0.64-0.91] $p = 0.003$). Children who exceeded two hours TST were 23% less likely to be in high physical activity group (OR, 0.71 [95% CI, 0.59-0.84] $p < 0.001$).

6.4.3. Model two (individual and family level factors)

None of the family level factors were found to be associated with high physical activity. Parents having third level education and an authoritative parenting style were both positively associated with moderate physical activity levels (Table 16). Children who had parents with a third level degree were 1.74 times more likely to be in the moderate physical activity group compared to children of parents with a lower secondary education or less (OR 1.74 [95% CI: 1.18-2.57] $p < 0.01$). Having a parent who adopts an authoritative parenting style was associated with a 42% increase in the child's probability of being in the moderate physical activity group (OR 1.42 [95% CI: 1.06-1.87] $p = 0.02$) compared to having a parent with a permissive parenting style.

In model two, the strength of the association for three of the significant individual level factors (gender, weight status and being a member of a sports or fitness team) became stronger. In particular, the probability of being in the high physical activity group was 66% higher for boys (OR: 1.66 [95% CI: 1.37-2.01] $p < 0.01$).

6.4.4. Model three (fully adjusted model)

Figure 5 illustrates the findings of the final model of the multivariate multinomial logistic regression analyses. Accounting for both individual and family level factors, active travel to and from school was positively associated with high physical activity levels. A positive association between living in a neighbourhood with after school activities and moderate physical activity was also identified. Children who used active mode of travel both to and from school were 34% more likely to be in the high physical activity group (OR 1.34 [95% CI: 1.03-1.74] $p = 0.03$) compared to children who used an inactive mode of travel both to and from school. Children living in a neighbourhood with after school activities were 39% more likely to be in the moderate physical activity group compared to those who lived in neighbourhoods without after school activities (OR 1.39 [95% CI: 1.05-1.84] $p = 0.02$).

The association between the individual level factors and high physical activity remained statistically significant. Of the family level factors, having a parent with third level education and authoritative parenting styles remained positively associated with moderate physical activity levels. None of the family level factors were associated with high physical activity.

6.5. Discussion

6.5.1. Main findings

To our knowledge, this is the first study to explore the multilevel effects of individual, family and environmental factors on physical activity levels of children in Ireland. A key finding of this research is that individual level factors appear to have the strongest association with physical activity levels in nine year olds. Further, many of these factors are modifiable. Being a member of a sports or fitness club and, having an active favourite hobby were both positively associated with higher levels of physical activity. Exceeding two hours of TST and being overweight or obese were negatively correlated with higher physical activity levels. No significant associations with the family level and just one marginal association among the environmental level factors were identified. However, the local or community environment may provide an appropriate setting for implementing physical activity initiatives including supporting sports participation.

Consistent with both extensive reviews by Sallis et al, 2000 [332] and van der Horst et al, 2007 [341] boys were more likely to have high physical activity levels than girls. Literature suggests that differences in organised sports participation may be responsible for some of gender disparities in physical activity levels. In this research, over 75% of the children were members of a sports or fitness group (84% of boys versus 67% of girls, $p = 0.000$). In the fully adjusted model (controlled for gender), this research found children who were members of a sports or fitness group were almost twice as likely to be in the high physical activity group compared to children who were not. This is consistent with findings of the review by Sallis et al, 2000 [332] which concluded that community sports participation was positively associated with higher physical activity levels. Despite generally higher sports participation among boys, a review of physical activity correlates among girls aged between 10 and 18 years also found that organised sports participation had a consistent positive association with higher physical activity levels [349]. Moreover, longitudinal studies have reported that participation in organised sports during childhood may be associated with long-term participation in physical activity in both adolescence and adulthood [328, 350]. The promotion of sports and other high intensity activities may therefore provide an opportunity to increase physical activity among school children.

Many sports and other high intensity activities take place as extra-curricular activities after school hours. The Irish primary school day typically lasts five hours and 40 minutes, commencing at 9am and finishing at approximately 3pm. While the curriculum recommends one hour of physical education per week, it has been suggested that many schools do not provide this [130]. As a result, children's preferences for extracurricular activities may also play a role in their overall physical activity levels. This research found that children reporting a preference for an active favourite hobby (including basketball, gymnastics and hockey) were more likely to be in the high physical activity group compared to children who preferred inactive favourite hobbies such as reading, listening to music, and watching TV. Similarly, in their review of previous research, Sallis et al, 2000 [332] concluded that children's preference for physical (rather than sedentary) activity was one of the factors most consistently associated with their participation in such activity.

Another key factor that may be associated with physical activity levels among nine year olds is sedentary behaviour. The American Academy of Paediatricians recommends that children do not exceed two hours of sedentary screen time per day [141]. Previous Irish research reported that over 99% of children and youth exceeded the recommended maximum two hours sedentary screen time per day. Conflicting evidence exists for an association between sedentary behaviours (including screen time) and physical activity levels among children [332, 351]. This present research found that exceeding these guidelines reduced the likelihood of high physical activity by 44%. The literature refers to the displacement theory as a possible explanation for an association between exceeding the recommended and lower physical activity, that is, sedentary behaviours may be replacing active behaviours [352]. However, other literature suggests that physical activity and sedentary behaviours are separate constructs [143, 353].

6.5.2. Social ecological theory

Physical activity behaviour and the factors influencing it are very complex. The social-ecological model adopted by this present research is a useful framework due to the complexity of behaviours [339]. Each level of the model layers (individual, family and environmental) is interconnected. Exploring the multiple domains, this present research has considered the broader context when identifying the predictors of physical activity. While this research did not identify environmental factors as major determinants of physical activity, more research is needed. In particular, the importance of built environments for increasing PA and other health behaviours has emerged in the literature [196, 354]. Hence, applying the social-ecological theory, objective measures of physical activity, along with more robust environmental level factors should be considered for modelling physical activity.

6.5.3. Physical activity and childhood obesity

This research used robust objectively measured data for calculating the child's weight status. While some previous evidence has reported inconclusive evidence between weight status and PA levels [332, 341], this research found that the weight status of the child was negatively associated with physical activity levels. Using objectively measured BMI data, being overweight or obese was associated with lower levels of physical activity. A possible explanation for this contrasting finding may be the use parent reported height and weight data for children in other research, which has been found to lack validity and reliability when compared with objective anthropometric measures [22].

6.5.4. Strengths and limitations

A key strength of this study is the large sample of nine year olds taken from the most comprehensive nationally representative children's health survey currently available in Ireland. According to the 2006 Census figures, there were 56,497 nine year old children resident in Ireland [343]. Thus, this data includes approximately one seventh of these children. Further, probability weights were applied to the data using survey data commands to ensure that the findings are national representative.

However, there are some limitations to this study. As this study is cross-sectional, bi-directional associations are possible. The sample only included nine year old children, hence, generalisability cannot be assumed for all children. Also, there was a relatively low response rate at the household level (57%). The data has been weighted to overcome any issues arising from this; however, response bias may exist.

Further, the nature of the physical activity data collected does not correspond with WHO guidelines (60 minutes of MVPA/day). The physical activity data available for this research was parent reported as opposed to objectively measured data. The parent reported physical activity based on how many days in the last 14 the study child had achieved at least 20 minutes of hard physical activity. This self-report question was found to be reliable with acceptable validity when compared with accelerometer data. Also, using this question, other Irish research has constructed physical activity categories in the same way [153]. Finally, this research provides a comprehensive list of individual level factors; however, some family and environmental level factors were not available such as the parent's physical activity patterns.

6.5.5. Conclusions

In conclusion, this study finds individual level factors; including many modifiable factors appear to have the strongest correlation with physical activity levels of nine year olds in Ireland. Individual level factors appear to predict physical activity levels when considered in the multiple domains. Future research should aim to use more robust objective measures to explore the usefulness of the interconnect that exists across these domains. In particular how the family and environmental settings could be useful facilitators for consistent individual level factors such as sports participation.

Table 14. Physical activity/obesity related characteristics of the children by gender and PA levels

		Boys					Girls			
		Low PA (N=826)	Moderate PA (N=728)	High PA (N=2,609)			Low PA (N=1,309)	Moderate PA (N=1,012)	High PA (N=2,082)	
INDIVIDUAL FACTORS[+]	**Total**	**N (%)**	**N (%)**	**N (%)**	**p-value**	**Total**	**N (%)**	**N (%)**	**N (%)**	**p-value**
Child's weight status**					<0.001					<0.001
Normal	3,100	558 (20)	541 (17)	2,001 (63)		3,019	812 (27)	692 (22)	1515(51)	
Overweight	661	137 (21)	115 (17)	409 (62)		875	296 (36)	204 (21)	375 (43)	
Obese	196	74 (39)	39 (18)	83 (43)		284	122 (48)	65 (20)	97 (33)	
Takes exercise					<0.001					<0.001
Never	34	22 (62)	4 (10)	8 (28)		44	25 (69)	7 (10)	12 (21)	
1-2times/week	673	243 (38)	144 (20)	286 (42)		957	446 (47)	223 (21)	288 (32)	
3-4times/week	939	209 (25)	234 (25)	496 (51)		1,136	356 (33)	329 (27)	453 (40)	
Almost every day	2,486	341 (16)	344 (14)	1801 (70)		2,244	472 (22)	450 (19)	1,322(59)	
Sports/fitness club					<0.001					<0.001
Yes	3,585	596 (18)	644 (18)	2345 (64)		3,137	809 (26)	768 (24)	1,560 (49)	
No	573	226 (41)	84 (14)	263 (45)		1,261	496 (40)	244 (16)	521 (44)	
Playing sport*					<0.001					0.11
Favourite [#]	1,657	232 (15)	258 (16)	1167 (69)		809	178 (23)	195 (24)	436 (53)	
Second favourite	968	155 (17)	187 (19)	636 (64)		767	207 (30)	179 (22)	381 (48)	
Third favourite	455	97 (27)	78 (16)	280 (57)		506	144 (31)	123 (22)	239 (48)	
Watching TV*					0.38					0.99
Favourite	169	53(29)	33 (19)	83 (52)		195	73 (35)	42 (20)	80 (45)	
Second favourite	491	126 (28)	88 (20)	277 (53)		428	144 (34)	94 (21)	190 (45)	
Third favourite	669	135 (23)	128 (18)	406 (59)		551	187 (35)	121 (21)	243 (44)	
Playing video games*					<0.001					0.36
Favourite	211	71 (37)	42 (17)	98 (46)		84	34 (35)	22 (29)	28 (36)	
Second favourite	318	84 (30)	64 (19)	170 (51)		202	61 (28)	54 (24)	87 (48)	
Third favourite	392	83 (21)	70 (18)	239 (62)		255	86 (36)	58 (20)	111(43)	

	Boys					Girls				
		Low PA	Moderate PA	High PA			Low PA	Moderate PA	High PA	
	Total	N (%)	N (%)	N (%)	p-value	Total	N (%)	N (%)	N (%)	p-value
Watching TV					<0.001					<0.001
Zero or <1 hour	1,050	157 (17)	174 (15)	719 (68)		1,186	274 (25)	279 (21)	633 (54)	
1-3hours	2,723	539 (21)	475 (18)	1,709 (62)		2,819	856 (30)	656 (22)	1,307 (47)	
>3hours	390	130 (35)	79 (21)	181 (44)		398	179 (45)	77 (19)	142 (36)	
Playing video games					<0.001					0.02
Zero or <1 hour	3,059	549 (20)	522 (17)	1,988 (63)		3,923	1,118 (29)	923 (22)	1,882 (48)	
1-3hours	1,011	245 (26)	185 (17)	581 (57)		438	169 (37)	82 (16)	187 (47)	
>3hours	93	32 (38)	21 (21)	40 (41)		39	19 (46)	7 (21)	13 (32)	
On the computer					<0.001					0.34
Zero or <1 hour	3,650	669 (21)	624 (17)	2,337 (62)		3,820	1,097 (30)	895 (22)	1,828 (48)	
1-3hours	498	143 (31)	94 (17)	261 (52)		549	200 (35)	112 (44)	237 (44)	
>3hours	33	14 (33)	9 (31)	10 (36)		32	11 (31)	5 (15)	16 (53)	
Total screen time					<0.001					0.002
<2hours/day	899	128 (17)	142 (14)	629 (69)		1,082	247 (25)	258 (22)	577 (53)	
>2hours/day	3,262	698 (23)	585 (18)	1,979 (59)		3,317	1,059 (32)	754 (22)	1,504 (46)	
FAMILY FACTORS[+]										
Parent weight* **					0.74					0.13
Normal	1,925	349 (21)	340 (17)	1,236 (62)		1,962	552 (29)	466 (21)	944 (50)	
Overweight	1,244	262 (22)	224 (18)	758 (60)		1,300	391 (31)	282 (21)	627 (47)	
Obese	655	149 (23)	112 (17)	394 (60)		1735	248 (35)	172 (23)	315 (43)	
Parent's education					0.01					<0.001
</=lower second level	674	156 (25)	108 (15)	410 (60)		834	281 (35)	151 (17)	402 (48)	
Higher second level	1,295	287 (23)	248 (19)	760 (58)		1,403	428 (31)	319 (22)	656 (47)	
Post second level	1,056	203 (21)	173 (16)	680 (63)		1,067	302 (27)	241 (23)	524 (50)	
Third level	1,138	180 (17)	199 (17)	759 (66)		1,099	298 (26)	301 (27)	500 (47)	
Siblings					0.59					0.17
Yes	3,716	728 (22)	656 (18)	2,332 (61)		3,977	1,166 (30)	910 (21)	1,901 (49)	
No	329	66 (20)	57 (16)	206 (64)		330	101 (32)	88 (26)	141 (42)	

		Boys					Girls			
		Low PA	Moderate PA	High PA			Low PA	Moderate PA	High PA	
	Total	N (%)	N (%)	N (%)	p-value	Total	N (%)	N (%)	N (%)	p-value
Household type					0.01					0.71
Single Parent	457	119 (28)	58 (14)	280 (59)		534	165 (32)	118 (20)	251 (48)	
Two parent	3,706	707 (21)	670 (18)	2,329 (61)		3,869	1,144 (31)	894 (22)	1,831 (47)	
Parenting style					0.53					0.09
Authoritative	3240	625 (21)	573 (18)	2042 (61)		3307	952 (30)	782 (23)	1573 (48)	
Permissive	626	131 (24)	113 (17)	382 (59)		807	269 (34)	174 (20)	364 (36)	
ENVIRONMENTAL FACTORS[+]										
Transport to school					0.21					0.68
Active	1,047	199 (23)	167 (15)	681 (62)		1,085	298 (30)	261 (22)	526 (49)	
Inactive	3,116	627 (22)	561 (18)	1,928 (60)		3,318	1,011 (31)	751 (21)	1,556 (47)	
Transport from school					0.24					0.48
Active	1,160	223 (23)	190 (15)	747 (63)		1,209	339 (30)	298 (23)	572 (48)	
Inactive	3,003	603 (21)	538 (18)	1,862 (60)		3,189	967 (31)	713 (21)	1,509 (48)	
School playground^					0.19					0.79
Fair/poor	1,660	320 (22)	316 (19)	1,024 (59)		1,704	501 (30)	398 (22)	805 (48)	
Good/excellent	2,361	453 (22)	389 (16)	1,489 (62)		2,493	751 (31)	573 (21)	1,169 (48)	
School sports facilities^					0.97					0.43
Fair/poor	1,765	343 (22)	310 (17)	1,112 (60)		1,908	573 (31)	417 (20)	918 (48)	
Good/excellent	2,267	460 (22)	397 (17)	1,410 (61)		2,341	698 (31)	563 (22)	1080 (47)	
Safe places to play					0.34					0.18
Agree	3,814	740 (22)	662 (17)	2412 (61)		4,016	1,194 (30)	925 (22)	1,897 (48)	
Disagree	344	85 (26)	64 (16)	195 (58)		113	381 (36)	87 (19)	181 (46)	
After school activities					0.05					0.17
Yes	3107	576 (20)	550 (18)	1981 (62)		3287	939 (30)	772 (22)	1576 (48)	
No	928	216 (25)	159 (17)	553 (58)		1020	334 (33)	225 (19)	461 (48)	

[+] all data is parent (primary caregiver) reported unless indicated otherwise , * child-reported variable

** weight status defined as BMI classified according to International Obesity Taskforce on Obesity age and gender specific guidelines using objectively measured height and weight data

*** weight status defined as BMI classified according to World Health Organisation guidelines using objectively measured height and weight data.

^ school principal reported data, [#] favourite refers to the study child reporting the hobby as being their favourite thing to do

Table 15. Univariate multinomial analysis of the individual, family and environmental factors on PA levels

Variable	Moderate PA* (N=1,740)		High PA* (N=4,691)	
	OR (95%CI)	p-value	OR (95%CI)	p-value
INDIVIDUAL FACTORS+				
Gender				
Boy	1.13 (0.96-1.33)	0.14	1.79 (1.55-2.07)	<0.001
Girl	1***		1	
Child's weight status#				
Obese	0.52 (0.38-0.71)	<0.001	0.34 (0.26-0.44)	<0.001
Overweight	0.78 (0.64-0.95)	0.01	0.71 (0.60-0.84)	<0.001
Normal	1		1	
Exercise/week**				
Almost every day	1.95 (1.59-2.38)	< 0.001	4.33 (3.64-5.15)	<0.001
3-4times/week	1.99 (1.59-2.45)	<0.001	1.93 (1.59-2.33)	<0.001
<twice/week	1		1	
Sports /fitness club				
Yes	2.49 (2.09-2.98)	<0.001	2.41 (2.0-2.82)	<0.001
No	1		1	
Favourite hobby**				
Active hobby^	1.26 (1.08-1.48)	0.01	1.81 (1.57-2.08)	<0.001
Inactive hobby	1		1	
Total screen time				
<Recommended 2 hours	0.83 (0.67-1.01)	0.06	0.66 (0.56-0.78)	<0.001
>Recommended 2 hours	1		1	
FAMILY FACTORS+				
Parent's weight status##				
Obese	0.86 (0.68-1.09)	0.21	0.77 (0.64-0.94)	0.01
Overweight	0.96 (0.79-1.17)	0.69	0.89 (0.76-1.04)	0.13
Normal	1		1	
Parent's employment				
Not in full time	1.31 (1.02-1.69)	0.04	1.23 (0.99 -1.53)	0.06
In full time work	1		1	
Parent's education				
Third level	1.93 (1.51-2.46)	<0.001	1.56 (1.28-1.90)	<0.001
Post-secondary	1.48 (1.17-1.87)	<0.001	1.35 (1.13-1.62)	0.001
Higher secondary	1.45 (1.16-1.79)	<0.001	1.10 (0.94-1.32)	0.23
< =Lower secondary	1		1	
Siblings				
Yes	0.92 (0.67-1.25)	0.57	1.02 (0.78-1.32)	0.90
No	1		1	
Household type				
Two parent	1.37 (1.07-1.75)	0.01	1.19 (0.99-1.45)	0.06
Single parent	1		1	
Parenting style				
Authoritative	1.26 (1.03-1.55)	0.02	1.22 (1.03-1.44)	0.02
Permissive	1		1	
ENVIRONMENTAL FACTORS+				
Travel to/from school				
Active both ways	0.94 (0.77-1.15)	0.54	1.02 (0.87-1.20)	0.80
Active one way	1.12 (0.83-1.52)	0.46	1.00 (0.79-1.28)	0.99
Inactive both ways	1		1	

Variable	Moderate PA* (N=1,740) OR (95%CI)	p-value	High PA* (N=4,691) OR (95%CI)	p-value
School playground* **				
Good/excellent	0.89 (0.74-1.06)	0.18	1.00 (0.86-1.18)	0.94
Fair/poor	1		1	
School sports facilities* **	1.08 (0.91-1.28)	0.37	1.03 (0.88-1.20)	0.75
Good/excellent	1		1	
Fair/poor				
Safe places to play				
Agree	1.20 (1.02-1.41)	0.03	1.20 (1.05-1.38)	0.01
Disagree	1		1	
After school activities				
Yes	1.29 (1.07-1.56)	0.01	1.22 (1.04-1.42)	0.01
No	1		1	

[+] all data is parent (primary caregiver) reported unless indicated otherwise
* reference category: low PA
** child-reported data
*** school principal reported data
**** 1 denotes reference category
^ active hobby was defined as one in which the study child had a physically active participatory role
[#] weight status defined as BMI classified according to International Obesity Taskforce on Obesity age and gender specific guidelines using objectively measured height and weight data
[##] weight status defined as BMI classified according to World Health Organisation guidelines using objectively measured height and weight data.

Figure 5. Individual, family and environmental factors associated with moderate and high physical activity

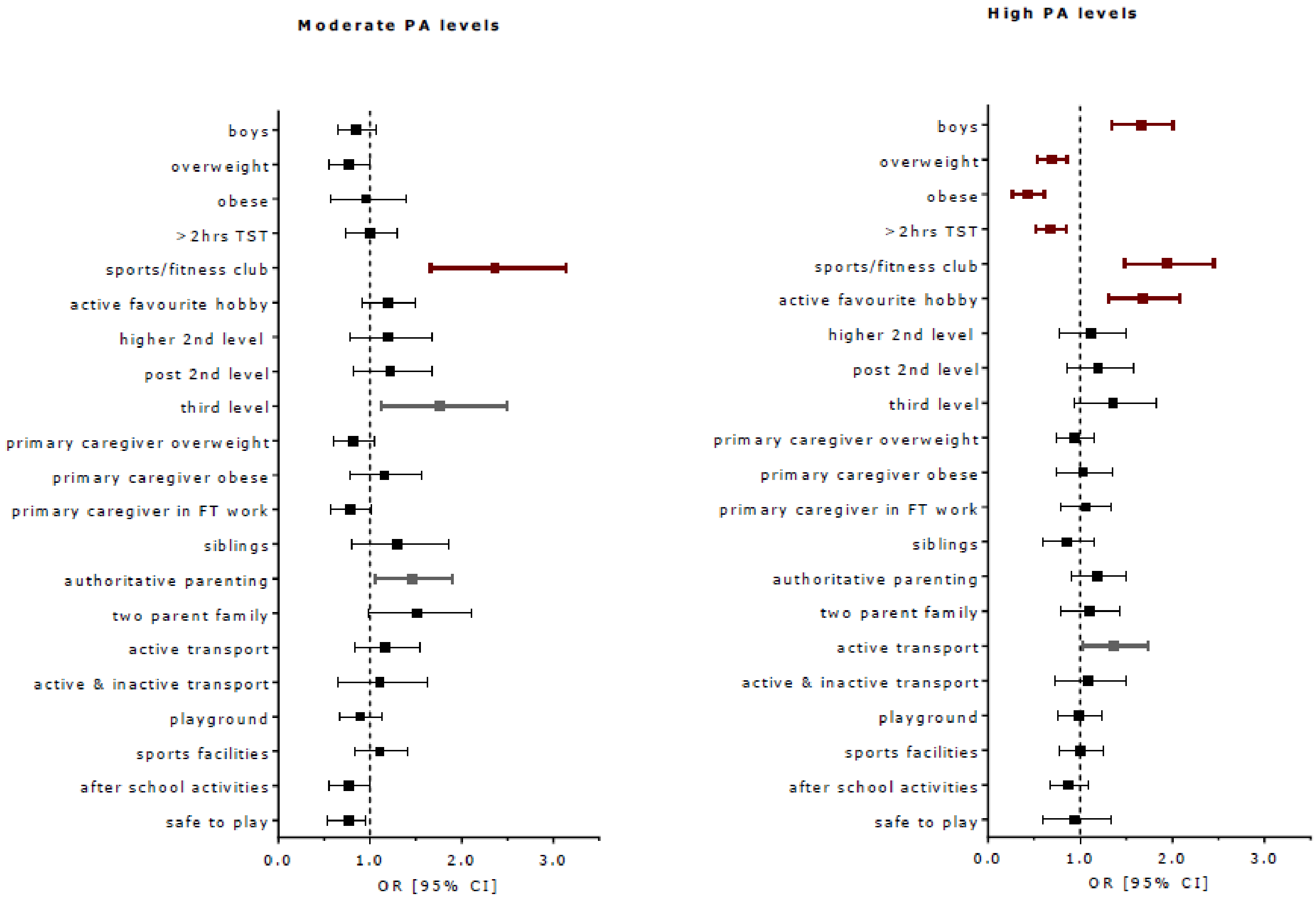

Table 16. Multivariate multinomial analysis of the individual, family and environmental factors on PA levels

	Model 1 (individual level factors)		Model 2 (model 1 + family level factors)		Model 3 (model 1 and 2 + environmental factors)	
	Moderate OR (95%CI)	High OR (95%CI)	Moderate OR (95%CI)	High OR (95%CI)	Moderate OR (95%CI)	High OR (95%CI)
INDIVIDUAL FACTORS +						
Gender						
Boy	0.96 (0.81-1.14)	1.54(1.32-1.80)	0.85 (0.68 -1.08)	1.66 (1.37-2.01)	0.84 (0.66-1.06)	1.64 (1.34-2.01)
Girl	1***	1	1	1	1	1
Child's weight status#						
Obese	0.58 (0.42-0.79)	0.40 (0.31-0.52)	0.86 (0.55-1.34)	0.41 (0.27-0.61)	0.90 (0.57-1.40)	0.41 (0.27-0.61)
Overweight	0.79 (0.65-0.97)	0.77 (0.64-0.91)	0.72 (0.55-1.34)	0.68 (0.54-0.85)	0.75 (.56-1.00)	0.68 (0.54-0.86)
Normal	1	1	1	1	1	1
Sports/fitness club						
Yes	2.28 (1.88-2.77)	1.86 (1.58-2.20)	2.32 (1.69-3.18)	1.92 (1.50-2.46)	2.28 (1.66-3.14)	1.90 (1.48-2.45)
No	1	1	1		1	1
Favourite hobby*						
Active	1.13 (0.95-1.35)	1.65 (1.42-1.92)	1.21 (0.95-1.53)	1.62 (1.30-2.03)	1.17 (0.91-1.50)	1.65 (1.31-2.08)
Inactive	1		1	1	1	1
Total screen time^						
< Recommended 2 hours	0.90 (0.73-1.11)	0.71 (0.59-0.84)	0.97 (0.73-1.28)	0.67 (0.53-0.86)	0.97 (0.73-1.30)	0.66 (0.52-0.85)
>Recommended 2hours	1	1	1	1	1	1
FAMILY FACTORS +						
Parent's weight#						
Obese			1.14 (0.82-1.58)	1.02(0.76-1.36)	1.11 (0.79-1.56)	1.00 (0.74-1.35)
Overweight			0.85 (0.65-1.11)	0.94 (0.75-1.17)	0.80 (0.61-1.05)	0.92 (0.74-1.16)
Normal			1	1	1	1
Parent's employment						
In full time work			0.81 (0.61-1.08)	1.05 (0.82-1.34)	0.76 (0.57-1.01)	1.04 (0.72-1.50)
Not in full time			1	1	1	1
Parent's education						
Third level			1.74 (1.18-2.57)	1.32 (0.96-1.81)	1.67 (1.12-2.50)	1.31 (0.94-1.83)
Post-secondary			1.21 (0.85-1.72)	1.17 (0.87-1.57)	1.14 (0.78-1.67)	1.16 (0.85-1.58)
Higher secondary			1.17 (0.81-1.68)	1.09 (0.80-1.47)	1.16 (0.81-1.68)	1.08 (0.79-1.49)
< =Lower secondary			1	1	1	1

	Model 1 (individual level factors)		Model 2 (model 1 + family level factors)		Model 3 (model 1 and 2 + environmental factors)	
	Moderate	High	Moderate	High	Moderate	High
	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)	OR (95%CI)
Siblings						
Yes			1.20 (0.80-1.79)	0.86 (0.62-1.18)	1.22 (0.80-1.86)	0.83 (0.59-1.16)
No			1	1	1	1
Household Structure						
Two parent			1.38 (0.96-1.98)	1.03(0.77-1.38)	1.45 (0.99-2.12)	1.07 (0.79-1.44)
One parent			1	1	1	1
Parenting style						
Authoritative			1.41 (1.07-1.87)	1.15 (0.90-1.47)	1.42 (1.06-1.90)	1.16 (0.91-1.49)
Permissive			1	1	1	1
ENVIRONMENTAL FACTORS+						
Travel to/from school						
Active both ways					1.13 (0.83-1.41)	1.34 (1.03-1.74)
Active one way					1.04 (0.66-1.62)	1.04 (0.72-1.50)
Inactive both ways					1	1
School playground**						
Good/excellent					0.87 (0.67-1.62)	0.97 (0.76-1.24)
Fair/poor					1	1
School sports facilities**						
Good/excellent					1.08 (0.83-1.41)	0.99 (0.78-1.26)
Fair/poor					1	1
Safe places to play						
Agree					0.81 (0.53-1.24)	1.12 -0.75-1.66)
Disagree					1	1
After school activities						
Yes					1.39 (1.05-1.84)	1.16 (0.92-1.46)
No					1	1

+ All data is primary caregiver reported unless indicated otherwise, *child-reported variable, ** school principal reported variable

 # objectively measured height and weight data, * 1 denotes reference category**

^ screen time was according to the American Association of Pediatrics guidelines

Table including p-values is located in the published paper in Appendix 8

Keane, E. 2014. *Childhood obesity in Ireland: recent trends and modifiable determinants*. PhD Thesis, University College Cork.

Please note that Chapter 7 (pp.162-184) is unavailable due to a restriction requested by the author.

8. MEASURED PARENTAL WEIGHT STATUS AND FAMILIAL SOCIO-ECONOMIC STATUS CORRELATES WITH CHILDHOOD OVERWEIGHT AND OBESITY AT AGE 9 (PAPER 6)

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THIS PAPER WAS PUBLISHED IN PLOS ONE IN 2012 (PLEASE SEE APPENDIX 8)

8.1. Abstract

Background

Parental obesity is a predominant risk factor for childhood obesity. Family factors including SES play a role in determining parent weight. It is essential to unpick how shared family factors impact on child weight. This study aims to investigate the association between measured parent weight status, familial socio-economic factors and the risk of childhood obesity at age 9.

Methods

Cross-sectional analysis of the first wave (2008) of the GUI Study. GUI is a nationally representative study of 9 year old children (N= 8,568). Schools were selected from the national total (response rate 82%) and age eligible children (response rate 57%) were invited to participate. Children and their parents had height and weight measurements taken using standard methods. Data were reweighted to account for the sampling design. Childhood overweight and obesity prevalence were calculated using IOTF definitions. Multinomial logistic regression examined the association between parent weight status, indicators of SES and child weight status.

Results

Overall, 25% of children were either overweight (19.3%) or obese (6.6%). Parental obesity was a significant predictor of child obesity. Of children with normal weight parents, 14.4% were overweight or obese whereas 46.2% of children with obese parents were overweight or obese. Maternal education and household class were more consistently associated with a child being in a higher BMI category than

household income. Adjusted regression indicated that female gender, one parent family type, lower maternal education, lower household class and a heavier parent weight status significantly increased the odds of childhood obesity.

Conclusion

Parental weight appears to be the most influential factor driving the childhood obesity epidemic in Ireland and is an independent predictor of child obesity across SES groups. Due to the high prevalence of obesity in parents and children, population based interventions are required.

8.2. Introduction

Parental obesity is well established as an important risk factor for childhood obesity (see Chapter 2 for more detail). [168, 169, 173, 175, 370]. Having an overweight parent doubles [176, 179] the risk of child obesity while obesity amongst both parents further increases the risk [175, 177, 179].

The relationship between parent and child weight is complex as it is a consequence of both shared genetic and environmental factors [10, 159, 371, 372]. SES is an important determinant of the shared family environment. Numerous studies have demonstrated an association between SES and obesity [373]. SES can influence lifestyle choices and behaviours, area of residence and food affordability, all of which are factors that have been shown to be associated with obesity [8, 11, 205, 320].

The inverse association between SES and obesity in adults is well established [9]. However, evidence of a relationship between childhood obesity and SES remains equivocal [159, 183, 184, 374, 375]. Variation in the types and definition of SES indicators used in studies may partly explain this. A review by Shrewsbury and Wardle [183] suggested that the association between child weight and SES is dependent on the type of SES indicator assessed. Parental education appeared to be most consistently associated with childhood obesity [183]. However, evidence of an association between household class and household income with child obesity remained less consistent [183].

As the prevalence of childhood overweight and obesity is high, it is essential to unpick how shared family factors impact on child weight. Understanding the underlying pathways to childhood obesity will help in the development of effective policies and interventions against child obesity. This present research utilizes nationally representative data containing detailed information on three key indicators of SES as well as objective measures of parental weight status and this provides a unique opportunity to determine the effect of different family factors on childhood obesity. This present study aims to (1) estimate the prevalence of childhood overweight and obesity by measured parental weight status and a range of SES indicators and (2) investigate the association between parental weight status, familial socio-economic characteristics and the risk of childhood obesity at age 9.

8.3. Methods

8.3.1. Ethics Statement

Written informed consent was obtained from a parent/guardian and the study child prior to data collection commencing. Ethical approval was granted by the Research Ethics Committee of the Health Research Board based in Dublin, Ireland.

8.3.2. Study design and sample

The study sample comprised of 8,568 nine-year old children who participated in the first wave (2007/2008) of the GUI Study [228]. GUI is a nationally representative cohort of 9 year old children residing in the Republic of Ireland. The sample was collected using a two-stage sampling method within the national school system. Eligible children were those who were born between the 1st November 1997 and the 31st October 1998. In the first stage, 1,105 primary schools from the national total of 3,200 were randomly selected using a PPS sampling method. In the second stage, a random sample of eligible children were selected from within each school. At the school level, a response rate of 82% was achieved, while at the household level (i.e. eligible child selected within the school) 57% of children and their parents participated in the study. The data was probability weighted prior to analysis to account for the complex sampling design. This involved the structural adjustment of the study sample to the population level whilst maintaining the case base of 8,568 children [343, 344].

8.3.3. Procedures

Trained social interviewers conducted computer assisted personal interviews with the study child and both parents/guardians (where applicable) within the home. Parents nominated a primary caregiver (the parent who spent most time with the study child) who was the primary respondent. Mothers were the primary caregiver for 98% of the study children. Responses to sensitive questions were self-reported on a paper questionnaire.

8.3.4. Anthropometric measures

Anthropometric measurements were obtained during the household interview using validated methods [344]. The interviewers were responsible for height and weight measurements of each study child and each adult respondent. Height was recorded to the nearest millimetre using a Leicester portable height stick. Weight was recorded using a SECA 761 flat mechanic scales to the nearest 0.5 kilogram. Study children and their parents were asked to wear light clothing for the weight measurement. Children were classified as normal weight, overweight (a BMI of 19.46 for boys and 19.45 for girls) or obese (a BMI of 23.39 for boys and 23.46 for girls) using age and gender specific IOTF definitions [27]. Measured parent BMI was classified according to the WHO classifications as normal weight (<25kg/m^2), overweight (≥25 and <30kg/m^2) or obese (≥30kg/m^2) [1].

8.3.5. Covariates

Parent reported variables were study child's gender (male/female), family type (one parent/two parents), study child has siblings (yes/no), mother's current age and SES indicators. Mother's current age was categorized into four groups (<30, 30-39, 40-49, 50+). SES was assessed using three different indicators: household class, household income and mother's highest level of education [228]. Mother's highest level of education (as opposed to father's highest level of education) was chosen as they tended to be the primary caregiver. The mother's education variable was coded as follows: lower secondary education or less, higher secondary education, post-secondary education and third level education. Household class was measured using the Irish Central Statistics (CSO) Social Class Schema 1996 produced by aggregating occupations classified using the CSO's Standard Classification of Occupations. For two parent families where both parents were economically active and were in different classes, the higher of the social classes was assigned to the family [228]. Net household income was self-reported. Net income was adjusted for household composition and size.

A separate variable was constructed for mother's measured BMI classification and father's measured BMI classification. Both variables were coded: normal weight, overweight, obese, missing. A combined single index variable for parent weight status was constructed by combining the mother's and father's measured BMI variables and was coded as: single parent/ both parents normal weight (normal weight family), one parent overweight (in a two parent family), single parent/ both parents overweight (overweight family), one parent obese (in a two parent family), single parent/ both parents obese (obese family).

8.3.6. Missing Data

No/low levels (<2%) of missing values were found within most of the covariates. However, where large levels of missing data were observed, methods of representing these values were incorporated into the analysis. Net household income had a high number (N=626, 7.3%) of missing values. The continuous equivalised net income variable was imputed using the multiple imputation (MI) command in Stata. This variable was then re-coded and presented in quintiles.

Measured height and/or weight data was missing for 5.2% of mothers and 6.4% of fathers (where present). Statistical tests suggested that the height and weight data were not missing at random so the data could not be imputed. In order to account for missing data, 'missing data' categories were generated for the mothers measured BMI and fathers measured BMI variables. Measured BMI data was available for 95% of the study children. This gave an effective case base of 8,136 children for analysis.

8.3.7. Statistical analysis

Analysis was completed in Stata 12 IC (StataCorp LP, USA). Probability weights were applied using survey data commands to account for the complex survey design. Prevalence estimates for normal weight, overweight and obese children were obtained. Unadjusted multinomial logistic regression was used to determine the risk of childhood overweight or obesity compared to normal weight according to parental weight status and familial SES factors. Forward stepwise multinomial logistic regression was conducted to assess the relationship between parent weight status, SES factors and childhood overweight and obesity. Non-significant variables based on the univariate regression (mother's current age) were not included in the forward stepwise regression. Mother's measured BMI and father's measured BMI were not included during adjustment as they were combined to form the single index variable parent weight status. Each of the nested models presented in the results section were adjusted for socio demographic (study child's gender, family type and study child has siblings) variables and SES indicators. Model 1 included the social demographic variables and household class; model 2 further adjusted for maternal education; model 3 was further adjusted for household income. The final model (model 4) was adjusted for study child's gender, study child has siblings, household class, highest level of maternal education, household income and parent weight status.

8.4. Results

Measured BMI data was available for 8,136 (95%) children. Overall, 74.1% (95% CI, 72.8-75.3) of children were a normal weight, 19.3% (95% CI, 18.2-20.5) were overweight and 6.6% (95% CI, 5.9-7.4) were obese. The prevalence of normal weight, overweight and obese children by parent weight status and by indicators of familial SES is shown in Table 21.

In total, 30% of girls were overweight or obese compared with 22% of boys ($p<0.000$). Within each of the SES indicators, there was an inverse relationship between SES and the prevalence of child overweight and obese. Those ranked lower within each of the socio-economic variables (household income $p=0.013$, maternal education $p<0.000$ & household class $p<0.000$) were significantly more likely to be overweight or obese than those ranked at a higher position. A higher prevalence of overweight and obesity was found among children whose mothers were either overweight or obese compared with children whose fathers were overweight or obese ($p<0.000$). Overall, 47.2% (95% CI, 45.7%-48.7%) of mothers were normal weight whilst 20.6% (95% CI, 19.4%-21.8%) of fathers were normal weight. Of children from two parent families, only 12% had 2 normal weight parents while 39.2% had at least one obese parent. In total, 11% (95% CI, 8.5%-14.1%) of children with 2 normal weight parents were overweight or obese. This increased to 24.7% (95% CI, 21.8%-28%) when one parent was obese and to 49.2% (95% CI, 43.3%-55.1%) when both parents were obese. Of children from single parent families, 49.2% (95% CI, 45.1%-53.3%) had a normal weight parent and 20% (95% CI, 16.7%-23.9%) had an obese parent. Overall, 18.1% (95% CI, 14.1%-23%) of children from single parent families with a normal weight parent were overweight or obese. This increased to 34.1% (95% CI, 27.7%-41.2%) when the parent was overweight and 41% (95% CI, 32%-50.6%) when the parent was obese.

Table 22 presents the results of the univariate multinomial logistic regression analyses. Univariate regression indicates that female gender, one parent family type, being an only child, lower household class, lower maternal education, lower household income and higher parental BMI (mother's BMI, father's BMI and parent weight status) were all associated with a child being in a higher BMI category. Having an overweight parent (within mother's BMI, father's BMI and the combined single index variable parent weight status) consistently increased the odds of childhood overweight and obesity. Parent weight status was most strongly associated with childhood overweight and obesity. The univariate regression also indicated that a lower household class and lower maternal education were associated with greater odds of childhood obesity than household income.

Results of the forward stepwise multinomial logistic regression are presented Table 23 and 24 (please see Appendix 8 for table in published paper). Model one and model two are presented in table 23 while model 3 and model 4 are presented in Table 24. The social demographic variables, female gender (p<0.000) and one parent family type (p<0.000) were significantly associated with childhood obesity. One parent family type was no longer significantly associated with childhood obesity when the SES indicators were added to the model (model 3: p=0.173). When household income was added to model 3, household income was no longer significantly associated with the odds of a child being in a higher BMI category. However, the association between household class and maternal education with child BMI remained unchanged (when comparing model 3 to model 2).

In the fully adjusted model (Table 24, model 4), female gender, one parent family type, lower household class, lower maternal education and having overweight or obese parents significantly increased the odds of child obesity. Within model 4, children whose mothers were educated to less than a graduate level had at least double the odds of childhood obesity compared with those educated to a graduate level. A lower household class remained significantly associated with child obesity. Although not significant, lower levels of education and a lower household class were associated with an increased odds of childhood overweight. Parent weight status was most significantly associated with childhood overweight and obesity. Children with obese parents were at a significantly increased odds of overweight (odds ratio [OR] 3.9, 95% CI, 2.8-5.6) when compared to children with normal weight parents. The odds of childhood obesity were 15.3 (95% CI, 8.4-27.7) when the single parent/both parents were obese. The odds of childhood obesity increased by nearly 3 fold when the single parent/both parents were obese compared to the single parent/both parents being overweight.

8.5. Discussion

8.5.1. Main findings

Using nationally representative data this present study aimed to assess the association between measured parent weight status, familial SES factors and the odds of childhood obesity. This research has resulted in two principal findings. Firstly, parent weight status appears to be the most significant independent predictor of childhood obesity in Ireland. Children from families with overweight or obese parents were at a significantly higher odds of obesity than children with normal weight parents. Secondly, household class and maternal education are better predictors of childhood obesity than household income.

Only 18.9% of children were from families (either single parent or two parent families) with normal weight parents. Having normal weight parents appears to have a protective effect against the odds of childhood obesity. Only 14.4% of children from such families were overweight or obese whereas 46.2% of children with obese parents were overweight or obese. After adjustment for household socio-economic characteristics, children from obese parent families remained at greater than 15 (95% CI, 8.44-27.65) times the odds of obesity when compared to children from families with normal weight parents. This suggests that SES alone cannot explain the association between parent obesity and child obesity. SES indicators appear to only capture some shared familial environmental factors which can result in an increased weight status. The results highlight that the shared family environment is a multi-dimensional contributor to the obesity epidemic with both genetic and environmental origins.

Within this present study, children who were more deprived were at a higher odds of overweight and obesity, which is similar to results found in adults [9]. Children from one parent families were found to be at significantly higher odds of overweight and obesity than children from two parent families. Some research suggests that one parent families may have greater levels of social deprivation and this may play a role in explaining this [376]. However, our results indicate that parental weight was more predictive of overweight and obesity in children from single parent families than SES. There was an inverse association between household class and maternal education with childhood obesity. The association between household class and childhood obesity was more graded. Within the final adjusted model, children from a lower household class were at higher odds of obesity than children with lesser educated mothers. Research indicates that parental education is the SES indicator most consistently associated with childhood obesity [183, 374]. This may be because maternal education is a more stable indicator of SES over time than household income or household class. Maternal education is likely to influence factors including literacy as well as knowledge of healthy versus unhealthy behaviours which impact on weight status [373, 377]. As a higher level of education appears protective against child obesity, this suggests that education may be crucial in tackling the obesity epidemic. Overall, variations in odds of obesity by each indicator of SES suggest that household class, household income and maternal education may all influence different behaviours and choices that impact weight status. Further research is required to fully understand how each SES characteristic predicts behaviours which result in an increased weight status. In addition, efforts are necessary to standardise SES indicators and definitions used across studies.

8.5.2. Possible explanations for the findings

In this study SES indicators do not explain all the association between parent and child weight. Therefore, other causal pathways for childhood obesity need to be considered. Research from other studies of childhood obesity indicates that the weight status of parents from 2 parent families may interact [174, 175]. Mechanisms resulting in a positive energy balance in both parents appear to be more predictive of childhood obesity than such mechanisms in one parent. In this current research having 2 obese parents compared with one obese parent resulted in a 2 fold increase in the odds of childhood obesity.

A study by Wardle et al. [378] compared food, physical activity and lifestyle patterns in children from lean and obese families. This study found that children from obese families had higher preferences for fatty foods and sedentary activities and a lower preference for fruit and vegetable consumption. Such food and physical activity patterns may have a negative impact on energy balance resulting in an increased weight status. Such diet and activity patterns may potentially explain the lack of significance for household income in this present study. Parent weight status may be a better predictor of food types purchased rather than income or other measures of household SES. More affluent families with obese parents may have a preference for energy dense food regardless of income available to spend on good quality foods. Grunert at al, [379] suggest that habitual behaviour is difficult to change even if an individual is aware of the negative consequences of their behaviours. Grunert et al, suggest that obese individuals have a greater response to external cues (sight, smell) for food intake whilst normal weight individuals respond to internal cues (hungry). Children may acquire habitual behaviours and responses to dietary and physical activity patterns from that of their parents. Another possible explanation is that genotypes including the FTO gene which impacts appetite may influence control over food intake and choices resulting in children from obese families having a greater predisposition for obesity [73, 380-382].

Similar to other findings [383, 384], maternal obesity was more predictive of a child being in a higher BMI category than paternal obesity. There are a number of possible explanations for this. Mothers were nominated as the primary caregiver (the person who spent most time with the study child) for 98% of children who took part in this study. This indicates that children spend more time in their mother's environment and thus may acquire more behaviour's from their mother. A study by Hannon et al, [385] found that the eating habits of the family food preparer, 84% of whom were mothers, predicted the eating habits of their child. Birth factors including the role of the intra-uterine environment on subsequent risk of childhood obesity is a second possible explanation [386, 387].

8.5.3. Strengths and Limitations

GUI is a large and nationally representative sample. The sample equates to approximately one in seven of all births in Ireland in 1997. The results of the study are applicable at a population level as a result of applying the sampling weights. All objective BMI measurements were measured by trained professionals using standardised techniques. The study contains information on three indicators of SES (household class, equivalised household income and maternal highest level of education). Imputing the household income variable decreased the amount of missing data.

However, there are several limitations to the study. There was a relatively low response rate at the household level (57%). The data have been weighed to adjust for the sampling strategy and response rate. However, there may be residual response bias. Of the children with measured BMI, there was missing values for BMI for 5.2% of mothers and 6.9% of fathers. Data was also missing for income for 7.3% of the households. While the missing data imputation procedure has enhanced the study power, it would have been preferable not to have missing data on this key variable.

8.5.4. Conclusions

Parent weight status is a significant predictor of childhood obesity. Children from lower household class families and those with lesser educated mothers were at an increased odds of childhood obesity. Early intervention is required to tackle the problem of childhood obesity. It may be suggested to target interventions at families where parents are overweight or obese. However, we must consider that in the current study, this includes the majority (81%) of families. Thus, the findings highlight the need for broadly based population level interventions targeting the social, economic and cultural dimensions of overweight and obesity. Further research is needed to assess how behaviours that affect energy balance vary between families with normal weight parents versus families with obese parents.

Table 21. Prevalence of normal weight, overweight and obese 9 year old children by parental weight and family socio-economic status indicators

			Prevalence N=8136		
	Total N=8136		Normal weight N =6120	Overweight N= 1545	Obese N =471
	N	%	N (%)	N (%)	N (%)
Gender					
Boy	3958	51.3	3101 (78.0)	661 (16.6)	196 (5.4)
Girl	4178	48.7	3019 (70.0)	884 (22.2)	275 (7.8)
Family type					
Two parents	7215	82.2	5474 (74.6)	1352 (19.3)	389 (6.1)
One parent	921	17.8	646 (71.6)	193 (19.7)	82 (8.7)
Has siblings					
Yes	7340	89.7	5569 (74.9)	1346 (18.6)	425 (6.5)
No	626	8.8	431 (66.0)	156 (26.1)	39 (7.9)
Mothers age					
<30	497	9.0	350 (70.7)	108 (21.3)	39 (8.0)
30-39	3107	41.3	2303 (73.5)	609 (19.5)	195 (7.0)
40-49	4271	46.8	3282 (75.5)	775 (18.7)	214 (5.7)
50+	219	2.9	156 (70.6)	47 (23.2)	16 (6.2)
Household class					
Professional workers	1114	8.3	926 (81.9)	165 (16.0)	23 (2.1)
Managerial and technical	3154	33.5	2418 (76.6)	594 (18.6)	142 (4.7)
Non-manual	1598	18.7	1177 (72.8)	316 (20.5)	105 (6.8)
Skilled manual	1137	16.6	809 (71.6)	234 (20.1)	94 (8.3)
Semi- skilled and unskilled	702	10.9	479 (66.0)	157 (23.0)	66 (11.0)
Unclassified class	431	12.0	311 (74.4)	79 (17.5)	41 (8.1)
Equivalised household annual income (in quintiles)					
Highest	2007	20.1	1575 (76.9)	363 (18.8)	69 (4.3)
4th	1734	20.1	1301 (73.8)	347 (19.9)	86 (6.4)
3rd	1513	20.2	1120 (73.9)	289 (19.9)	104 (6.2)
2nd	1300	20.0	969 (72.6)	241 (20.1)	90 (7.3)
Lowest	993	19.6	718 (73.6)	184 (17.4)	91 (9.0)
Highest level of maternal education					
Third level education	2103	16.9	1694 (80.6)	349 (16.6)	60 (2.8)
Post secondary education	2007	16.0	1513 (75.2)	384 (19.1)	110 (5.7)
Higher secondary education	2560	37.2	1908 (74.6)	493 (19.3)	159 (6.1)
Lower secondary education or less	1412	30.0	968 (69.3)	311 (21.3)	133 (9.4)
Mothers measured BMI classification					
Normal	3836	47.2	3207 (82.9)	543 (14.6)	86 (2.5)
Overweight	2491	31.6	1796 (70.7)	523 (21.5)	172 (7.9)
Obese	1349	19.2	804 (59.7)	371 (27.2)	174 (13.1)
Missing	177	2.0	135 (78.2)	30 (14.7)	12 (7.1)

			Normal weight N (%)	Overweight N (%)	Obese N (%)
Fathers measured BMI classification					
Normal	1506	20.6	1276 (83)	192 (14.2)	38 (2.8)
Overweight	3439	47.0	2680 (77.7)	608 (17.7)	151 (4.6)
Obese	1713	25.6	1107 (63.9)	451 (25.5)	155 (10.6)
Missing data	452	6.9%	325 (67.7)	88 (22)	39 (10.3)
Parent Weight Status					
Single parent/both parents normal weight	1271	18.9	1104 (85.6)	146 (12.6)	21 (1.8)
One overweight (2 parent family)	2139	26.7	1803 (83.2)	284 (14.13)	52 (2.7)
Single parent/both parents overweight	1340	18.8	977 (72.4)	276 (20.3)	87 (7.3)
One obese (2 parent family)	1922	25.8	1317 (68.2)	466 (23.9)	139 (7.9)
Single parent/both parents obese	575	9.9	297 (53.8)	180 (29.5)	98 (16.7)

Table 22. Association between parental weight status, family socio-economic status indicators and the risk of child overweight and obesity

	Overweight		Obese	
	OR (95% CI)	*P*	OR (95% CI)	*P*
Gender				
Boy	1		1	
Girl	1.49 (1.29-1.72)	0.000	1.61 (1.27-2.03)	0.000
Family type				
Two parent	1		1	
One parents	1.07 (0.87-1.31)	0.529	1.47 (1.09-2)	0.013
Has siblings				
Yes	1		1	
No	1.07 (1.01-1.14)	0.016	0.97 (0.86-1.1)	0.660
Mother's age				
<30	1		1	
30-39	0.88 (0.65-1.19)	0.404	0.84 (0.54-1.31)	0.445
40-49	0.82 (0.62-1.1)	0.181	0.67 (0.44-1.03)	0.065
50+	1.09 (0.67-1.78)	0.731	0.78 (0.38-1.6)	0.5
Household class				
Professional workers	1		1	
Managerial & technical	1.25 (0.97-1.61)	0.088	2.4 (1.35 - 4.26)	0.003
Non-manual	1.44 (1.11-1.88)	0.006	3.61 (1.96 - 6.64)	0.000
Skilled manual	1.44 (1.09-1.9)	0.011	4.49 (2.43 - 8.32)	0.000
Semi- skilled &unskilled	1.79 (1.32-2.43)	0.000	6.45 (3.41-12.18)	0.000
Unclassified class	1.21 (0.84-1.74)	0.306	4.2 (2.13-8.3)	0.000
Highest level of maternal education				
Third level education	1		1	
Post secondary education	1.23 (1-1.51)	0.046	2.21 (1.42-3.43)	0.000
Higher secondary education	1.26 (1.04-1.52)	0.018	2.4 (1.6-3.6)	0.000
Lower secondary education or less	1.49 (1.21-1.84)	0.000	3.96 (2.66-5.89)	0.000
Equivalised household annual income (in quintiles)				
Highest	1		1	
4th	1.1 (0.9-1.34)	0.353	1.53 (1.02-2.29)	0.038
3rd	1.1 (0.89-1.36)	0.378	1.5 (1.02-2.2)	0.041
2nd	1.13 (0.91-1.4)	0.276	1.79 (1.19-2.68)	0.005
Lowest	0.96 (0.75-1.24)	0.769	2.18 (1.44-3.31)	0.000
Mother's measured BMI classification				
Normal	1		1	
Overweight	1.73 (1.46-2.05)	0.000	3.65(2.64–5.06)	0.000
Obese	2.59 (2.12-3.16)	0.000	7.17 (5.13-10.03)	0.000
Missing data	1.07 (0.63-1.82)	0.799	2.98 (1.52-5.85)	0.002
Father's measured BMI classification				
Normal	1		1	
Overweight	1.33 (1.07-1.65)	0.010	1.74 (1.13-2.69)	0.012
Obese	2.33 (1.86-2.93)	0.000	4.92 (3.2-7.57)	0.000
Missing data	1.89 (1.33-2.69)	0.000	4.51 (2.56–7.97)	0.000

	Overweight		**Obese**	
	OR (95% CI)	***P***	**OR (95% CI)**	***P***
Parent Weight Status				
Single parent/both parents normal weight	1		1	
One overweight (2 parent family)	1.16 (0.89-1.50)	0.275	1.54 (0.85-2.79)	0.157
Single parent/both parents overweight	1.91 (1.45-2.50)	0.000	4.74 (2.70-8.32)	0.000
One obese (2 parent family)	2.39 (1.84-3.1)	0.000	5.42 (3.15-9.32)	0.000
Single parent/both parents obese	3.73 (2.69-5.17)	0.000	14.53 (8.17-25.85)	0.000

Table 23. Forward stepwise multinomial logistic regression

	Model 1				Model 2			
	Overweight		Obese		Overweight		Obese	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
Gender								
Boy	1		1		1		1	
Girl	1.47 (1.28-1.7)	0.000	1.52 (1.21-1.91)	0.000	1.46 (1.26-1.68)	0.000	1.48 (1.18-1.86)	0.001
Family type								
Two	1		1		1		1	
One	1.1 (0.86-1.4)	0.464	1.34 (0.94-1.9)	0.108	1.15 (0.9-1.47)	0.277	1.33 (0.93-1.91)	0.119
Siblings								
Yes	1		1		1		1	
No	1.07(1.01–1.13)	0.031	0.95 (0.83-1.08)	0.417	1.07 (1.01-1.13)	0.033	0.95 (0.83-1.09)	0.449
Household class								
Professional workers	1		1		1		1	
Managerial &technical	1.23 (0.95-1.6)	0.114	2.33 (1.31-4.16)	0.004	1.17 (0.90-1.52)	0.249	2.7 (1.61-4.52)	0.000
Non-manual	1.40 (1.07-1.83)	0.016	3.39 (1.81-6.33)	0.000	1.26 (0.94-1.69)	0.121	3.34 (1.93-5.78)	0.000
Skilled manual	1.40 (1.05-1.86)	0.021	4.37 (2.36-8.10)	0.000	1.27 (0.93-1.72)	0.127	3.98 (2.27-6.99)	0.000
Semi-skilled &unskilled	1.69 (1.24-2.31)	0.001	5.93 (3.1-11.35)	0.000	1.50 (1.07-2.10)	0.018	5.01 (2.76-9.09)	0.000
Unclassified class	1.11 (0.74-1.67)	0.602	3.26 (1.51-7.05)	0.003	0.97 (0.63-1.48)	0.888	2.75 (1.37-5.54)	0.005
Highest level of maternal education								
Third level	-		-		1		1	
Post secondary					1.18 (0.95-1.46)	0.131	1.91 (1.21-3.01)	0.005
Higher secondary					1.16 (0.94-1.43)	0.162	1.9 (1.23-2.94)	0.004
Lower secondary/ less					1.33 (1.05-1.70)	0.018	2.79 (1.77-4.39)	0.000

Table 24. Forward stepwise multinomial logistic regression (continued)

	Model 3				Model 4			
	Overweight		Obese		Overweight		Obese	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Gender								
Boy	1		1		1		1	
Girl	1.44 (1.24-1.67)	0.000	1.52 (1.19-1.94)	0.001	1.45 (1.24-1.70)	0.000	1.52 (1.15-2.0)	0.003
Family type								
Two	1		1		1		1	
One	1.23 (0.95-1.59)	0.112	1.3 (0.89-1.89)	0.173	1.47 (1.09-1.97)	0.011	1.83 (1.17-2.87)	0.009
Siblings								
Yes	1		1		1		1	
No	1.06 (1.0-1.14)	0.055	0.95 (0.83-1.10)	0.505	1.07 (0.99-1.14)	0.080	0.95 (0.83-1.09)	0.493
Household class								
Professional workers	1		1		1		1	
Managerial &technical	1.15 (0.88-1.5)	0.304	2.55 (1.51-4.31)	0.000	1.17 (0.88-1.57)	0.278	2.89 (1.55-5.39)	0.001
Non-manual	1.21 (0.89-1.65)	0.213	3.17 (1.81-5.55)	0.000	1.25 (0.9-1.75)	0.180	3.26 (1.7-6.25)	0.000
Skilled manual	1.26 (0.91-1.75)	0.156	3.78 (2.12-6.73)	0.000	1.32 (0.93-1.88)	0.120	4.0 (2.01-7.81)	0.000
Semi-skilled &unskilled	1.50 (1.06-2.14)	0.024	4.40 (2.36-8.20)	0.000	1.43 (0.98-2.1)	0.066	4.75 (2.29-9.86)	0.000
Unclassified class	0.97 (0.62-1.53)	0.898	2.62 (1.27-5.37)	0.009	0.94 (0.56-1.57)	0.805	2.13 (0.96-4.76)	0.064
Highest level of maternal education								
Third level education	1		1		1		1	
Post secondary education	1.2 (0.95-1.51)	0.120	1.89 (1.18-3.03)	0.008	1.18 (0.92-1.52)	0.202	2.29 (1.47-3.55)	0.000
Higher secondary education	1.17 (0.94-1.46)	0.156	1.81 (1.14-2.88)	0.012	1.11 (0.87-1.41)	0.422	2.05 (1.35-3.11)	0.001
Lower secondary education or less	1.41 (1.08-1.83)	0.010	2.79 (1.72-4.53)	0.000	1.22 (0.91-1.64)	0.117	2.7 (1.72-4.23)	0.000
Equivalised household annual income (in quintiles)								
Highest	1		1		1		1	
4^{th}	1.01 (0.82-1.24)	0.933	1.16 (0.77-1.75)	0.488	0.96 (0.77-1.2)	0.713	1.19 (0.76-1.86)	0.459
3^{rd}	0.96 (0.77-1.21)	0.744	0.94 (0.63-1.41)	0.780	0.93 (0.73-1.2)	0.589	0.96 (0.61-1.52)	0.873

	Model 3				Model 4			
	Overweight		Obese		Overweight		Obese	
	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*	OR (95% CI)	*P*
Equivalised household annual income (in quintiles)								
2nd	0.96 (0.75-1.21)	0.703	1.02 (0.66-1.58)	0.927	0.91 (0.71-1.18)	0.487	0.96 (0.59-1.55)	0.864
Lowest	0.81 (0.60-1.08)	0.146	1.11 (0.69-1.78)	0.656	0.75 (0.55-1.04)	0.083	1.04 (0.61-1.75)	0.895
Parent weight status								
Single parent/ both parents normal weight	-		-		1		1	
One overweight (2 parent family)					1.32 (0.99-1.77)	0.058	2.16 (1.16-4.18)	0.022
Single parent/both parents overweight					2.08 (1.56-2.79)	0.000	5.36 (2.95-9.72)	0.000
One obese (2 parent family)					2.66 (2.0-3.55)	0.000	6.88(3.76-12.61)	0.000
Single parent/both parents obese					3.94 (2.78-5.58)	0.000	15.28 (8.44-27.65)	0.000

Keane, E. 2014. *Childhood obesity in Ireland: recent trends and modifiable determinants*. PhD Thesis, University College Cork.

Please note that Chapter 9 (pp. 210-236) is unavailable due to a restriction requested by the author.

10. DISCUSSION

This thesis aimed to contribute to the current evidence base regarding the direction, magnitude and contribution of risk factors for childhood overweight and obesity. This chapter firstly outlines the main findings of this thesis. Secondly, the main strengths and limitations of this work are highlighted. Thirdly, potential areas for consideration by public health planners and policymakers are outlined. Fourthly, areas for future research are proposed. Finally, I provide a brief conclusion to this thesis.

10.1. Main findings

10.1.1. Trends

The systematic review collated data on prevalence rates of overweight and obesity from population samples of Irish school children between 2002 and 2012 (Chapter 3). As the methods used between studies varied, the results were difficult to interpret. However, consistent with other developed countries [32, 218], the prevalence of childhood overweight and obesity remained stable over the previous decade. There was some evidence to suggest that childhood obesity rates may have decreased slightly. However, one in four Irish children remained either overweight or obese during this 10 year period.

10.1.2. Determinants

Using social-ecological theory, risk factors for childhood overweight and obesity were examined at an individual, family and environmental level. Diet, physical activity and sedentary behaviour were assessed as individual level lifestyle factors. A higher proportion of overweight and obese child engaged in unhealthy lifestyle behaviours than normal weight children (see Chapters 5, 6 and 7). Overweight and obese children had a lower diet quality and a higher energy intake (kcals) when compared to normal weight children. A high contribution of daily energy intake in all children was from unhealthy kidDASH components, especially those who were overweight and obese. A one unit increase in kidDASH was significantly associated with a decreased risk of childhood overweight and obesity (RR 0.97, 95% CI, 0.95-0.99, p=0.002).

Individual level factors were more strongly associated with physical activity levels in nine year old children than family or environmental level factors (Chapter 6). In particular, being a member of a sports or fitness club and having an active favourite hobby were positively associated with higher levels of physical activity. Exceeding two hours of TST and being overweight or obese were negatively associated with higher physical activity levels.

Normal weight children engaged in approximately 20 minutes extra of MVPA per day than overweight and obese children (Chapter 7). Time spent at MVPA was inversely associated with the risk of childhood overweight and obesity independent of sedentary time. By contrast, sedentary time was not associated with the risk of overweight and obesity independent of MVPA. However, TST was independently associated with the risk of childhood overweight and obesity. This suggests that how sedentary time is spent may be a stronger risk factor for overweight and obesity than overall time spent sedentary.

Family and environmental level risk factors for overweight and obesity were explored using GUI Study data (Chapters 8 and 9). At a family level, parent weight status and the SES of the family were assessed. Only one in five children had two normal weight parents (or a normal weight single parent). Parental obesity and each of the SES indicators (social class, highest level of maternal education and equivalised household income) were associated with childhood overweight and obesity in univariate analyses. In multivariate analyses, parental weight status remained a strong risk factor for childhood overweight and obesity. Highest level of maternal education and social class were also significantly associated with the odds of obesity but not with overweight. However, household income was not associated with childhood overweight or obesity after adjustment. This suggests that each SES variable operates via a different pathway to influence the odds of childhood overweight and obesity.

The impact of access to food outlets in the local area on diet quality and BMI was explored as an environmental level risk factor. The distance to and density of convenience stores or supermarkets in the local area did not significantly impact on dietary quality or BMI in children. However, there was some evidence that household SES did influence diet quality and BMI. These findings are in contrast to data from Irish adults where an association between food access and dietary quality was found [205]. A possible explanation for the lack of an association may be due to the limited variation in the DQS.

10.2. Strengths and limitations

This section provides a synopsis of the overall strengths and limitations of this thesis. The strengths and limitations of the seven papers in this thesis have been acknowledged and addressed in the previous chapters.

This thesis has addressed a timely and relevant research question in Ireland. The Department of Health in Ireland published the Healthy Ireland report in 2013 and set a target to reduce the prevalence of overweight and obesity in Irish children by 6% by 2019 [408]. The systematic review has provided data on trends in overweight and obesity prevalence in the 10 years prior to this target being set. This thesis has also provided some current data on risk factors for childhood overweight and obesity. If a downward population level shift in the prevalence of childhood overweight and obesity is to be achieved, an in-depth understanding of the current aetiology of obesity is needed. The relevance of the findings is highlighted as this work has been presented at scientific conferences both nationally or internationally. To date, four of the included papers have been published in peer reviewed scientific journals. Two invited pieces of work have been published, one by a national level stakeholder with a specific policy focus. In addition, a national level organisation, Safefood, has used the findings of the CCLaS Study to inform their current obesity campaign. This work has also attracted attention from local, national, print and broadcast media (see Tables 44-48 in Appendices 6 and 7).

Two relatively large studies were used to explore risk factors for overweight and obesity. The GUI Study is a nationally represent study which collected data on a wide range of risk factors. The CCLaS Study collected in-depth data on lifestyle factors, data which are sparse in Ireland. Both studies included objective measurements. The outcome variable (weight status) was objectively measured in both studies. Many of the main risk factors were carefully measured and well defined. Accelerometer derived physical activity and sedentary time variables were explored. Energy under-reporting was considered when assessing the dietary data to account for measurement error. Objectively measured parental BMI, numerous measures of family level SES and GIS food access data was also available for this thesis. Data on a number of important confounders were also available and considered within each of the included results chapters.

Key practical, ethical and epidemiological considerations were taken into account during the conduct and reporting of this research. Practical and ethical considerations addressed as part of the CCLaS Study are outlined in Chapter 4. Careful consideration was given to the selection and adjustment of confounders. Missing data was imputed where appropriate. Missing data categories were generated to describe non-responders or to reduce the quantity of missing data where deemed appropriate. Multicollinearity was also considered where there may have been excessive correlation between covariates. As measurement error is associated with the reporting of dietary intake especially in obese children [409, 410], this thesis identified energy under reporters and stratified results in Chapters 5 and 6. Data reduction techniques were chosen for the accelerometers based on the current evidence base. The clustering of children within schools was accounted for during analysis of the CCLaS Study.

This thesis also has a number of limitations. As the data used in this thesis is cross-sectional, causal inference must be tentative. There are well established criteria for causal inference which are extensively used in the interpretation of findings in epidemiological research. Causal inference in science is always uncertain and this is particularly the case in relation to epidemiology, even with the most robust research designs (cohort studies and randomised controlled trials). There are particular concerns regarding causal inference in cross-sectional studies as we measure the cause and effect at the same time. In the case of the exposures and outcomes examined in this thesis, for example, physical activity and obesity, bi-directional associations are possible.

The limited age of the children in the CCLaS and GUI Studies may reduce the external validity of the findings of this thesis, as the findings may not be generalisable to children of all ages. Non-responder bias may be a problem for both the GUI and CCLaS Studies though sampling weights were available to account for imbalances in the GUI data. No information was available on the children who did not participate in the GUI and CCLaS studies. Data on some important confounders such as pubertal status was not available. As the data in this thesis is from observational studies, residual confounding is a possibility. Residual confounding may have occurred if confounders were either unaccounted for or if measured with poor precision such as if categories of included confounders were too broad.

Habitual dietary intake and physical activity are difficult to measure, define and interpret in children (see Chapter 2, 5 and 7 for more detail) [96]. For the CCLaS Study, feasibility and practicality were considered when deciding how to measure diet and physical activity as both are susceptible to measurement error and bias. Measurement error applies to all our exposures and outcomes in epidemiology. This need not be a problem provided that the error is random and the sample size is relatively large. By contrast, bias is always of concern, either selection bias (eg. non-response bias) or measurement bias (recall or social desirability bias). Social desirability bias can arise if children change their behaviours during the measurement period and this is especially a problem during analysis if the error is systematic. The food diary used in the CCLaS Study had not been validated prior to data collection and further work is needed to test the validity and reliability of this measurement tool. Accelerometers can underestimate some activities such as cycling when located on the wrist. This may result in non-random error. To date, there is no consensus on the best data reduction techniques for accelerometers. This limits the comparability and generalisability of findings.

10.3. Public health and policy implications

10.3.1. Monitoring of childhood overweight and obesity rates

Traditionally, the monitoring of height and weight in Irish children has been inadequate. It is important that child height and weight are routinely monitored. In 2008, the first round of the WHO Childhood Obesity Surveillance Initiative commenced where the height and weight of a sample of children aged 7 was measured. In 2010, children aged 7 and 9 had measures taken and in 2012 children aged 7, 9 and 11 had measurements taken.

In addition, the Health Service Executive is piloting the inclusion of height and weight measurements as part of the routine school health check where the hearing and eyesight of children in senior infants (children aged 5-7 years) is tested. These initiatives are important for monitoring trends over time and will allow for public health planning. However, the systematic review (Chapter 3) highlighted that efforts are needed to standardise the methods used between studies to allow for increased comparability of prevalence data.

10.3.2. Preventative strategies and interventions

The recent Healthy Ireland initiative has set out to reduce the prevalence of overweight and obesity in Irish children by 6% by 2019 [408]. In order to achieve this downward distribution in the prevalence of overweight and obesity, a population level approach to preventing overweight and obesity is needed. To date, Ireland has very few preventative strategies or interventions which target obesity. To my knowledge, the Safefood childhood obesity campaign is the only population based campaign currently tackling obesity in Irish children [411]. The Safefood campaign promotes positive lifestyle behaviours including a healthy diet, portion size control, regular physical activity, lower levels of screen time and adequate sleep. However, the effectiveness of this campaign has not yet been quantified.

It seems practical to target all children rather than those who are susceptible to becoming overweight, especially as risk factors such as parental obesity (Chapter 8) are common. In addition, weak associations from ratio based data in epidemiologic studies may translate into large absolute changes in the incidence of disease where the outcome of interest is common [412]. Thus, it is essential that we tackle predominant lifestyle behaviours associated with obesity along with wider contextual factors.

This thesis suggests that we increasingly need to consider the context in which obesity related choices are made to develop effective, sustainable strategies. This is especially important as simple preventative strategies targeting diet and/or physical activity, have not brought use closer to understanding how to reverse the obesity epidemic [71, 362]. While individual lifestyle choices are associated with overweight and obesity (see Chapters 5-7), wider environmental factors, particularly the shared family environment (Chapters 6, 8 and Appendix 4), were associated with an increased odds of obesity. To date, in Ireland, preventative strategies which consider the wider context in which obesity related behaviours occurs are lacking.

A number of suggestions regarding lifestyle, especially diet and physical activity can be made based on the findings of this thesis. Firstly, promoting healthy eating patterns by encouraging children to follow healthy eating guidelines may be an effective means of tackling obesity. In addition, targeting specific aspects of diet which are predominant contributors to obesity such as SSBs is important. Promoting 'healthy' foods consumed in low quantities by children such as fruit, vegetables and whole grains may also be useful. For example, children who attend disadvantaged schools in Ireland have lunch provided. Thus, incorporating more 'healthy' lunch options such as fruit or whole grains and reducing the availability of sugary juice drinks is worth considering.

Overweight and obesity children spent 20 minutes less per day engaging in MVPA than normal weight children on week and weekend days. Reducing the gap in mean time spent at MVPA per day could be made a target for policy makers. This is especially noteworthy as the debate as to whether physical activity should be made compulsory in schools in Ireland continues. However, as a gap in time spent at MVPA was also evident on weekend days, the home and local environment should also be targeted. Reducing screen time is also important as sedentary behaviour is common in children.

If obesity policies and strategies targeting lifestyle are to be effective, the complex web of risk factors associated with diet, physical activity and obesity need to be considered. In particular, the role of the home environment needs to be taken into account as parents play an important role in determining child weight status. Parental choices and the home environment can influence children's lifestyle choices and behaviours. Therefore, strategies need to tackle barriers to a healthy lifestyle at a household or community level. The potential role of the local environment in Ireland remains unknown and needs further consideration. Though, food access was not an important determinant of BMI, other aspects of the community may influence the risk of obesity. For example, increasing sports participation in the local community may reduce household barriers to being physically active. In addition, targeting the physical environment by increasing connectivity, safety, lighting and cleanliness may increase walkability and physical activity levels within the community.

Furthermore, the complexity and magnitude of overweight and obesity suggests that multifaceted policies and strategies across many levels are needed [413]. Capacity building strategies are needed to utilise expertise from many sectors including public health, education, media, agriculture and the food industry to target obesity. Co-ordinated efforts at a community, organisational and government level have the potential to target lifestyle choices and obesity. Regulation may be one particularly promising area to tackle unhealthy choices. For example, increased regulation in the food sector could target food production, food labelling and food marketing. SSBs taxation may also potentially reduce consumption of sugary drinks, energy intake and obesity risk at a societal level [414]. Such measures could help protect children against an unhealthy lifestyle.

10.4. Future research recommendations

Further research should focus on standardising methods and definitions for measuring BMI in children. This would help increase the comparability of findings across studies. Some longitudinal research on the determinants of childhood obesity in Ireland is needed. The GUI Study is a longitudinal study and as further waves of the data are made available, this will allow us to develop a deeper understanding of determinants of obesity over time in Ireland. Further research is also needed to understanding the interaction of risk factors across levels of influence. In particular, research is needed to understand how different ecological contexts (eg. local environment, school environment, macro environment) contribute to diet, physical activity and obesity. There is also a need to design and pilot obesity interventions which target both lifestyle behaviours as well as the context in which these behaviours occur.

10.5. Conclusion

Childhood overweight and obesity prevalence has remained stable over the previous decade. However, prevalence rates are unacceptably high with one in four children either overweight or obese. This thesis has demonstrated that a complex set of risk factors are associated with childhood obesity. Diet and physical activity are core factors associated with childhood overweight and obesity. However, contextual factors, especially the shared family environment, are also important determinants for childhood obesity. As risk factors for childhood overweight and obesity are common, population levels strategies and interventions are needed. A multifaceted approach to tackle the problem is needed to achieve a measurable decrease in the prevalence of overweight and obesity. From a practical perspective, tackling modifiable barriers to making healthy lifestyle choices at a home, community or wider societal level is required.

11. REFERENCES

1. World Health Organization: **Obesity: preventing and managing the global epidemic**. In *World Health Organization Technical Report Series*. Geneva; 2000.
2. Wang Y, Lobstein T: **Worldwide trends in childhood overweight and obesity**. *International Journal of Pediatric Obesity* 2006, **1**(1):11-25.
3. World Health Organization: **Population-based prevention strategies for childhood obesity**. Geneva 2010.
4. Himes JH: **Challenges of Accurately Measuring and Using BMI and Other Indicators of Obesity in Children**. *Pediatrics* 2009, **124**(Supplement 1):S3-S22.
5. Hu FB: *Obesity Epidemiology*. New York: Oxford University Press, Inc; 2008.
6. Hill JO, Wyatt HR, Peters JC: **Energy Balance and Obesity**. *Circulation* 2012, **126**(1):126-132.
7. Butland B, Jebb S, Kopelman P, McPherson K, Thomas S, Mardell J, Parry V: **Foresight. Tackling obesities: future choices - project report**. 2nd edition. London, UK: Department of Innovation, Universities and Skills; 2007.
8. Rosenkranz RR, Dzewaltowski DA: **Model of the home food environment pertaining to childhood obesity**. *Nutrition Reviews* 2008, **66**(3):123-140.
9. Sobal J, Stunkard AJ: **Socioeconomic status and obesity: a review of the literature**. *Psychological bulletin* 1989, **105**(2):260.
10. Maes HH, Neale MC, Eaves LJ: **Genetic and Environmental Factors in Relative Body Weight and Human Adiposity**. *Behavior Genetics* 1997, **27**(4):325.
11. Booth KM, Pinkston MM, Poston WSC: **Obesity and the Built Environment**. *J Am Diet Assoc* 2005, **105**(supplement 5):110-117.
12. Doak C, Visscher T, Renders C, Seidell J: **The prevention of overweight and obesity in children and adolescents: a review of interventions and programmes**. *Obesity reviews* 2006, **7**(1):111-136.
13. Peters JC: **Combating obesity: challenges and choices**. *Obesity Research* 2003, **11**(S10):7S-11S.
14. Han JC, Lawlor DA, Kimm SYS: **Childhood obesity**. *The Lancet*, **375**(9727):1737-1748.
15. Barak F, Falahi E, Keshteli AH, Yazdannik A, Esmaillzadeh A: **Adherence to the Dietary Approaches to Stop Hypertension (DASH) diet in relation to obesity among Iranian female nurses**. *Public health nutrition* 2014:1-8.
16. Mei Z, Grummer-Strawn LM, Pietrobelli A, Goulding A, Goran MI, Dietz WH: **Validity of body mass index compared with other body-composition screening indexes for the assessment of body fatness in children and adolescents**. *Am J Clin Nutr* 2002, **75**:978-985.
17. Mei Z, Grummer-Strawn LM, Wang J, Thornton JC, Freedman DS, Pierson RN, Dietz WH, Horlick M: **Do Skinfold Measurements Provide Additional Information to Body Mass Index in the Assessment of Body Fatness Among Children and Adolescents?** *Pediatrics* 2007, **119**(6):e1306-e1313.
18. Ellis KJ: **Selected body composition methods can be used in field studies**. *The Journal of nutrition* 2001, **131**(5):1589S-1595S.
19. Wells J: **A critique of the expression of paediatric body composition data**. *Archives of disease in childhood* 2001, **85**(1):67-72.
20. Sherry B, Jefferds ME, Grummer-Strawn LM: **Accuracy of adolescent self-report of height and weight in assessing overweight status: a literature review**. *Archives of Pediatrics & Adolescent Medicine* 2007, **161**(12):1154.
21. Shiely F, Perry IJ, Lutomski J, Harrington J, Kelleher CC, McGee H, Hayes K: **Temporal trends in misclassification patterns of measured and self-report based body mass index categories-findings from three population surveys in Ireland**. *BMC Public Health* 2010, **10**(1):560.

22. Akinbami LJ, Ogden CL: **Childhood Overweight Prevalence in the United States: The Impact of Parent-reported Height and Weight**. *Obesity* 2009, **17**(8):1574-1580.
23. Rothman K, Greenland S: *Modern Epidemiology*. 2nd edition. Philadelphia: Lippincott-Raven Publishers; 1998.
24. Murphy JFA: **The National Taskforce on Obesity**. *Irish Medical Journal* 2005, **98**(5):132-132.
25. O'Neill JL, McCarthy SN, Burke SJ, Hannon EM, Kiely M, Flynn A, Flynn MAT, Gibney MJ: **Prevalence of overweight and obesity in Irish school children, using four different definitions**. *European Journal of Clinical Nutrition* 2007, **61**(6):743-751.
26. Ogden CL, Yanovski SZ, Carroll MD, Flegal KM: **The Epidemiology of Obesity**. *Gastroenterology* 2007, **132**(6):2087-2102.
27. Cole TJ, Bellizzi MC, Flegal KM, Dietz WH: **Establishing a standard definition for child overweight and obesity worldwide: international survey**. *BMJ* 2000, **320**(7244):1240.
28. Rolland-Cachera MF: **Childhood obesity: current definitions and recommendations for their use**. *International Journal of Pediatric Obesity* 2011, **6**(5-6):325-331.
29. Neovius MG, Linné YM, Barkeling BS, Rossner SO: **Sensitivity and specificity of classification systems for fatness in adolescents**. *The American Journal of Clinical Nutrition* 2004, **80**(3):597-603.
30. Cole TJ, Lobstein T: **Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity**. *Pediatric Obesity* 2012, **7**(4):284-294.
31. Lobstein T, Baur L, Uauy R: **Obesity in children and young people: A crisis in public health**. *Obesity Reviews, Supplement* 2004, **5**(1):4-104.
32. Rokholm B, Baker J, Sørensen T: **The levelling off of the obesity epidemic since the year 1999–a review of evidence and perspectives**. *Obesity reviews* 2010, **11**(12):835-846.
33. Jackson-Leach R, Lobstein T: **Estimated burden of paediatric obesity and co-morbidities in Europe. Part 1. The increase in the prevalence of child obesity in Europe is itself increasing**. *International Journal of Pediatric Obesity* 2006, **1**(1):26-32.
34. Lobstein T, Frelut ML: **Prevalence of overweight among children in Europe**. *Obesity reviews* 2003, **4**(4):195-200.
35. Wijnhoven TMA, Van Raaij JMA, Spinelli A, Rito AI, Hovengen R, Kunesova M, Starc G, Rutter H, Sjoberg A, Petrauskiene A *et al*: **Who european childhood obesity surveillance initiative: Inter-country results from first 12 who member states**. *Obesity Facts* 2012, **5**:13-14.
36. Wijnhoven TM, van Raaij JM, Spinelli A, Starc G, Hassapidou M, Spiroski I, Rutter H, Martos É, Rito AI, Hovengen R: **WHO European Childhood Obesity Surveillance Initiative: body mass index and level of overweight among 6-9-year-old children from school year 2007/2008 to school year 2009/2010**. *BMC Public Health* 2014, **14**(1):806.
37. Ogden CL, Flegal KM, Carroll MD, Johnson CL: **Prevalence and trends in overweight among US children and adolescents, 1999-2000**. *JAMA: The Journal of the American Medical Association* 2002, **288**(14):1728-1732.
38. Hedley AA, Ogden CL, Johnson CL, Carroll MD, Curtin LR, Flegal KM: **Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002**. *JAMA: The Journal of the American Medical Association* 2004, **291**(23):2847-2850.
39. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM: **Prevalence of overweight and obesity in the United States, 1999-2004**. *JAMA* 2006, **295**:1549-1555.

40. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM: **Prevalence of high body mass index in US children and adolescents, 2007-2008**. *JAMA: The Journal of the American Medical Association* 2010, **303**(3):242-249.
41. Ogden CL, Carroll MD, Kit BK, Flegal KM: **Prevalence of Obesity and Trends in Body Mass Index Among US Children and Adolescents, 1999-2010**. *JAMA: The Journal of the American Medical Association* 2012, **307**(5):483-490.
42. Ogden CL, Carroll MD, Kit BK, Flegal KM: **Prevalence of childhood and adult obesity in the United States, 2011-2012**. *JAMA* 2014, **311**(8):806-814.
43. Skinner AC, Skelton JA: **Prevalence and trends in obesity and severe obesity among children in the United States, 1999-2012**. *JAMA pediatrics* 2014.
44. Cunningham SA, Kramer MR, Narayan KV: **Incidence of Childhood Obesity in the United States**. *New England Journal of Medicine* 2014, **370**(5):403-411.
45. Must A, Strauss RS: **Risks and consequences of childhood and adolescent obesity**. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity* 1999, **23**:S2-11.
46. Dietz WH: **Health consequences of obesity in youth: childhood predictors of adult disease**. *Pediatrics* 1998, **101**(Supplement 2):518-525.
47. Finucane F: **Obesity in Irish youth: epidemiology and implications**. *Irish Journal of Medical Science* 2009, **178**(3):249-255.
48. Baker JL, Olsen LW, Sørensen TI: **Childhood body-mass index and the risk of coronary heart disease in adulthood**. *New England Journal of Medicine* 2007, **357**(23):2329-2337.
49. Freedman DS, Dietz WH, Srinivasan SR, Berenson GS: **The relation of overweight to cardiovascular risk factors among children and adolescents: the Bogalusa Heart Study**. *Pediatrics* 1999, **103**:1175-1182.
50. Vissers D, Vanroy C, De Meulenaere A, Van de Sompel A, Truijen S, Van Gaal L: **Metabolic syndrome in youth: a cross-sectional school-based survey**. *Acta Pædiatrica* 2007, **96**(12):1809-1813.
51. Whincup PH, Deanfield JE: **Childhood obesity and cardiovascular disease: the challenge ahead**. *Nature Clinical Practice Cardiovascular Medicine* 2005, **2**(9):432-433.
52. Griffiths LJ, Parsons TJ, Hill AJ: **Self-esteem and quality of life in obese children and adolescents: A systematic review**. *International Journal of Pediatric Obesity* 2010, **5**(4):282-304.
53. Dee A, Kearns K, Ciaran O, Sharp L, Staines A, Victoria O, Fitzgerald S, Perry IJ: **The direct and indirect costs of both overweight and obesity: a systematic review**. *BMC research notes* 2014, **7**(1):242.
54. Reilly JJ, Methven E, McDowell ZC, Hacking B, Alexander D, Stewart L, Kelnar CJ: **Health consequences of obesity**. *Archives of disease in childhood* 2003, **88**(9):748-752.
55. Strauss RS: **Childhood obesity and self-esteem**. *Pediatrics* 2000, **105**(1):e15-e15.
56. Lawlor DA, Benfield L, Logue J, Tilling K, Howe LD, Fraser A, Cherry L, Watt P, Ness AR, Smith GD: **Association between general and central adiposity in childhood, and change in these, with cardiovascular risk factors in adolescence: prospective cohort study**. *BMJ* 2010, **341**.
57. Smith S, Sumar B, Dixon K: **Musculoskeletal pain in overweight and obese children**. *International Journal of Obesity* 2013, **38**(1):11-15.
58. Beuther DA, Weiss ST, Sutherland ER: **Obesity and asthma**. *American Journal of Respiratory and Critical Care Medicine* 2006, **174**(2):112-119.

59. Park M, Falconer C, Viner R, Kinra S: **The impact of childhood obesity on morbidity and mortality in adulthood: a systematic review**. *Obesity reviews* 2012, **13**(11):985-1000.
60. Reilly J, Kelly J: **Long-term impact of overweight and obesity in childhood and adolescence on morbidity and premature mortality in adulthood: systematic review**. *International Journal of Obesity* 2010, **35**(7):891-898.
61. Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T: **Do Obese Children Become Obese Adults? A Review of the Literature**. *Preventive medicine* 1993, **22**(2):167-177.
62. Wabitsch M: **Overweight and obesity in European children: definition and diagnostic procedures, risk factors and consequences for later health outcome**. *European Journal of Pediatrics* 2000, **159**(1):S8-S13.
63. Cawley J: **The economics of childhood obesity**. *Health Affairs* 2010, **29**(3):364-371.
64. Trasande L, Chatterjee S: **The impact of obesity on health service utilization and costs in childhood**. *Obesity* 2009, **17**(9):1749-1754.
65. Trasande L, Liu Y, Fryer G, Weitzman M: **Effects of childhood obesity on hospital care and costs, 1999–2005**. *Health Affairs* 2009, **28**(4):w751-w760.
66. Finkelstein EA, Trogdon JG, Cohen JW, Dietz W: **Annual medical spending attributable to obesity: payer-and service-specific estimates**. *Health Affairs* 2009, **28**(5):w822-w831.
67. Wang Y, Beydoun MA, Liang L, Caballero B, Kumanyika SK: **Will all Americans become overweight or obese? Estimating the progression and cost of the US obesity epidemic**. *Obesity* 2008, **16**(10):2323-2330.
68. Dee A, Perry IJ, Staines A, O'Neill C, McVeigh T, al. e: **Executive Summary: The cost of overweight and obesity on the island of Ireland. Safefood.**; 2012.
69. Keaver L, Webber L, Dee A, Shiely F, Marsh T, Balanda K, Perry I: **Application of the UK foresight obesity model in ireland: the health and economic consequences of projected obesity trends in ireland**. *PLoS One* 2013, **8**(11):e79827.
70. Finegood DT, Merth TDN, Rutter H: **Implications of the Foresight Obesity System Map for Solutions to Childhood Obesity**. *Obesity* 2010, **18**(n1s):S13-S16.
71. Summerbell C, Waters E, Edmunds L, Kelly S, Brown T, Campbell K: **Interventions for preventing obesity in children**. *Cochrane Database Syst Rev* 2005, **3**(3).
72. Prentice AM, Jebb SA: **Obesity in Britain: gluttony or sloth?** *BMJ* 1995, **311**:437-439.
73. Wells JCK, Siervo M: **Obesity and energy balance: is the tail wagging the dog?** *Eur J Clin Nutr* 2011, **65**(11):1173-1189.
74. Weinsier RL, Hunter GR, Heini AF, Goran MI, Sell SM: **The etiology of obesity: relative contribution of metabolic factors, diet, and physical activity**. *Am J Med* 1998, **105**:145-150.
75. Hill JO, Wyatt HR, Reed GW, Peters JC: **Obesity and the environment: where do we go from here?** *Science* 2003, **299**(5608):853-855.
76. Swinburn BA, Sacks G, Hall KD, McPherson K, Finegood DT, Moodie ML, Gortmaker SL: **The global obesity pandemic: shaped by global drivers and local environments**. *The Lancet* 2011, **378**(9793):804-814.
77. Katz D: **Unfattening our children: forks over feet**. *International Journal of Obesity* 2010, **35**(1):33-37.
78. Brug J, te Velde SJ, Chinapaw MJ, Bere E, De Bourdeaudhuij I, Moore H, Maes L, Jensen J, Manios Y, Lien N: **Evidence-based development of school-based and family-involved prevention of overweight across Europe: the ENERGY-project's design and conceptual framework**. *BMC Public Health* 2010, **10**(1):276.

79. Swinburn B, Egger G, Raza F: **Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity**. *Preventive medicine* 1999, **29**(6):563-570.
80. Edelstein S: *Nutrition in Public Health: A Handbook for Developing Programs and Services*. 3rd edition. London: Jones & Bartlett Learning International; 2011.
81. Bleich SN, Ku R, Wang YC: **Relative contribution of energy intake and energy expenditure to childhood obesity: a review of the literature and directions for future research**. *Int J Obes* 2011, **35**(1):1-15.
82. Lytle LA: **Examining the etiology of childhood obesity: The IDEA study**. *American journal of community psychology* 2009, **44**(3-4):338-349.
83. Glanz K, Rimer B, Viswanath K: *Health behaviour and health education: theories, research and practice* 4th edition. San Francisco, CA: Jossey Bass; 2008.
84. Davison KK, Birch LL: **Childhood overweight: a contextual model and recommendations for future research**. *Obesity reviews* 2001, **2**(3):159-171.
85. Story M, Kaphingst KM, Robinson-O'Brien R, Glanz K: **Creating healthy food and eating environments: policy and environmental approaches**. *Annu Rev Public Health* 2008, **29**:253-272.
86. Blundell JE, Stubbs RJ, Golding C, Croden F, Alam R, Whybrow S, Le Noury J, Lawton CL: **Resistance and susceptibility to weight gain: Individual variability in response to a high-fat diet**. *Physiology & Behavior* 2005, **86**(5):614-622.
87. Kipping RR, Jago R, Lawlor DA: **Obesity in children. Part 1: Epidemiology, measurement, risk factors, and screening**. *BMJ* 2008, **337**.
88. Popkin BM: **Contemporary nutritional transition: determinants of diet and its impact on body composition**. *Proceedings of the Nutrition Society* 2011, **70**(01):82-91.
89. Drewnowski A, Popkin BM: **The nutrition transition: new trends in the global diet**. *Nutrition Reviews* 1997, **55**(2):31-43.
90. Hu FB: **Dietary pattern analysis: a new direction in nutritional epidemiology**. *Current opinion in lipidology* 2002, **13**(1):3.
91. Moeller SM, Reedy J, Millen AE, Dixon LB, Newby P, Tucker KL, Krebs-Smith SM, Guenther PM: **Dietary patterns: challenges and opportunities in dietary patterns research: an Experimental Biology workshop, April 1, 2006**. *Journal of the American Dietetic Association* 2007, **107**(7):1233-1239.
92. Lazarou C, Newby PK: **Use of Dietary Indexes among Children in Developed Countries**. *Advances in Nutrition: An International Review Journal* 2011, **2**(4):295-303.
93. Webb G: *Nutrition: a health promotion approach*. 3rd edition edition. London: Hodder Arnold; 2008.
94. Collins CE, Watson J, Burrows T: **Measuring dietary intake in children and adolescents in the context of overweight and obesity**. *International Journal of Obesity* 2010, **34**(7):1103-1115.
95. Gibney MJ, Margetts BM, Kearney JM, L. A: *Public health nutrition*. Oxford: Blackwell Science 2004.
96. Willett W: *Nutritional epidemiology*. *Volume 40*: Oxford University Press; 2013.
97. World Health Organization: **Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation**. *Volume 916*. Diamond Pocket Books (P) Ltd.; 2003.
98. Walton J, McNulty BA, Nugent AP, Gibney MJ, Flynn A: **Diet, lifestyle and body weight in Irish children: findings from Irish Universities Nutrition Alliance national surveys**. *Proceedings of the Nutrition Society* 2014, **73**(02):190-200.

99. Bradlee ML, Singer MR, Qureshi MM, Moore LL: **Food group intake and central obesity among children and adolescents in the Third National Health and Nutrition Examination Survey (NHANES III)**. *Public health nutrition* 2010, **13**(6):797-805.
100. Newby P: **Plant foods and plant-based diets: protective against childhood obesity?** *The American Journal of Clinical Nutrition* 2009:ajcn. 26736G.
101. Tohill BC, Seymour J, Serdula M, Kettel-Khan L, Rolls BJ: **What epidemiologic studies tell us about the relationship between fruit and vegetable consumption and body weight**. *Nutrition Reviews* 2004, **62**(10):365-374.
102. Ledoux T, Hingle M, Baranowski T: **Relationship of fruit and vegetable intake with adiposity: a systematic review**. *Obesity reviews* 2011, **12**(5):e143-e150.
103. Choumenkovitch SF, McKeown NM, Tovar A, Hyatt RR, Kraak VI, Hastings AV, Herzog JB, Economos CD: **Whole grain consumption is inversely associated with BMI Z-score in rural school-aged children**. *Public health nutrition* 2013, **16**(02):212-218.
104. St-Onge MP, Keller KL, Heymsfield SB: **Changes in childhood food consumption patterns: a cause for concern in light of increasing body weights**. *The American Journal of Clinical Nutrition* 2003, **78**(6):1068-1073.
105. Nielsen SJ, Popkin BM: **Changes in beverage intake between 1977 and 2001**. *American Journal of Preventive Medicine* 2004, **27**(3):205-210.
106. Bowman SA, Gortmaker SL, Ebbeling CB, Pereira MA, Ludwig DS: **Effects of fast-food consumption on energy intake and diet quality among children in a national household survey**. *Pediatrics* 2004, **113**(1):112-118.
107. Ludwig DS, Peterson KE, Gortmaker SL: **Relation between consumption of sugar-sweetened drinks and childhood obesity: a prospective, observational analysis**. *Lancet* 2001, **357**:505-508.
108. Grimes CA, Riddell LJ, Campbell KJ, Nowson CA: **Dietary Salt Intake, Sugar-Sweetened Beverage Consumption, and Obesity Risk**. *Pediatrics* 2013, **131**(1):14-21.
109. Kant AK: **Indexes of overall diet quality: a review**. *Journal of the American Dietetic Association* 1996, **96**(8):785-791.
110. Jacques PF, Tucker KL: **Are dietary patterns useful for understanding the role of diet in chronic disease?** *The American Journal of Clinical Nutrition* 2001, **73**(1):1-2.
111. Patrick H, Nicklas TA: **A review of family and social determinants of children's eating patterns and diet quality**. *Journal of the American College of Nutrition* 2005, **24**(2):83-92.
112. Ocké MC: **Evaluation of methodologies for assessing the overall diet: dietary quality scores and dietary pattern analysis**. *Proceedings of the Nutrition Society* 2013, **72**(02):191-199.
113. Arvaniti F, Panagiotakos DB: **Healthy indexes in public health practice and research: a review**. *Critical reviews in food science and nutrition* 2008, **48**(4):317-327.
114. Jennings A, Welch A, van Sluijs EM, Griffin SJ, Cassidy A: **Diet quality is independently associated with weight status in children aged 9–10 years**. *The Journal of nutrition* 2011, **141**(3):453-459.
115. Kontogianni MD, Farmaki AE, Vidra N, Sofrona S, Magkanari F, Yannakoulia M: **Associations between lifestyle patterns and body mass index in a sample of Greek children and adolescents**. *Journal of the American Dietetic Association* 2010, **110**(2):215-221.

116. Lazarou C, Panagiotakos DB, Matalas A-L: **Physical activity mediates the protective effect of the Mediterranean diet on children's obesity status: The CYKIDS study**. *Nutrition* 2010, **26**(1):61-67.
117. Feskanich D, Rockett HRH, Colditz GA: **Modifying the healthy eating index to assess diet quality in children and adolescents**. *Journal of the American Dietetic Association* 2004, **104**(9):1375-1383.
118. World Health Organization: **Global recommendations of phyisical activity for health**. Geneva: World Health Organization,; 2010.
119. Trost SG: **State of the Art Reviews: Measurement of Physical Activity in Children and Adolescents**. *American Journal of Lifestyle Medicine* 2007, **1**(4):299-314.
120. Hills AP, King NA, Armstrong TP: **The contribution of physical activity and sedentary behaviours to the growth and development of children and adolescents**. *Sports Medicine* 2007, **37**(6):533-545.
121. Janssen I, LeBlanc AG: **Review Systematic review of the health benefits of physical activity and fitness in school-aged children and youth**. *International Journal of Behavioral Nutrition and Physical Activity* 2010, **7**(40):1-16.
122. Koplan J, Liverman CT, Kraak VI: *Preventing childhood obesity: health in the balance*: Natl Academy Pr; 2005.
123. Rachele JN, McPhail SM, Washington TL, Cuddihy TF: **Practical physical activity measurement in youth: a review of contemporary approaches**. *World Journal of Pediatrics* 2012, **8**(3):207-216.
124. Baranowski T: **Reliability and Validity of Self Report of Aerobic Activity: Family Health Project**. *Research Quarterly for Exercise and Sport* 1984, **55**(4):309-317.
125. Reilly JJ, Penpraze V, Hislop J, Davies G, Grant S, Paton JY: **Objective measurement of physical activity and sedentary behaviour: review with new data**. *Archives of disease in childhood* 2008, **93**(7):614-619.
126. Yıldırım M, Verloigne M, De Bourdeaudhuij I, Androutsos O, Manios Y, Felső R, Kovács É, Doessegger A, Bringolf-Isler B, te Velde S: **Study protocol of physical activity and sedentary behaviour measurement among schoolchildren by accelerometry-Cross-sectional survey as part of the ENERGY-project**. *BMC Public Health* 2011, **11**(1):182.
127. Rowlands AV: **Accelerometer assessment of physical activity in children: an update**. *Pediatric Exercise Science* 2007, **19**(3):252-266.
128. Esliger DW, Copeland JL, Barnes JD, Tremblay MS: **Standardizing and Optimizing the Use of Accelerometer Data for Free-Living Physical Activity Monitoring**. *Journal of physical activity & health* 2005, **2**(3):366.
129. Verloigne M, Van Lippevelde W, Maes L, Yıldırım M, Chinapaw M, Manios Y, Androutsos O, Kovács É, Bringolf-Isler B, Brug J: **Levels of physical activity and sedentary time among 10-to 12-year-old boys and girls across 5 European countries using accelerometers: an observational study within the ENERGY-project**. *International Journal of Behavioral Nutrition and Physical Activity* 2012, **9**(1):34.
130. Woods CB, Tannehill D, Walsh J: **The Children's Sport Participation and Physical Activity Study (CSPPA)**. *Fifth Physical Education, Physical Activity and Youth Sport (PE PAYS)* 2010:1.
131. Kelly C, Gavin A, Molcho M, Nic Gabhainn S: **The Irish health behaviour in school-aged children (HBSC) study 2010**. Department of Health and National University of Ireland, Galway; 2012.
132. Riddoch CJ, Mattocks C, Deere K, Sounders J, Kirkby J, Tilling K, Leary SD, Blair SN, Ness AR: **Objective measurement of levels and patterns of physical activity**. *Archives of disease in childhood* 2007, **92**(11):963-969.

133. Jiménez-Pavón D, Kelly J, Reilly JJ: **Associations between objectively measured habitual physical activity and adiposity in children and adolescents: Systematic review**. *International Journal of Pediatric Obesity* 2010, **5**(1):3-18.
134. Prentice-Dunn H, Prentice-Dunn S: **Physical activity, sedentary behavior, and childhood obesity: a review of cross-sectional studies**. *Psychology, health & medicine* 2012, **17**(3):255-273.
135. Wilks D, Besson H, Lindroos A, Ekelund U: **Objectively measured physical activity and obesity prevention in children, adolescents and adults: a systematic review of prospective studies**. *Obesity reviews* 2011, **12**(5):e119-e129.
136. Steele RM, van Sluijs EM, Cassidy A, Griffin SJ, Ekelund U: **Targeting sedentary time or moderate- and vigorous-intensity activity: independent relations with adiposity in a population-based sample of 10-y-old British children**. *The American Journal of Clinical Nutrition* 2009, **90**(5):1185-1192.
137. Chaput JP, Lambert M, Mathieu ME, Tremblay MS, O' Loughlin J, Tremblay A: **Physical activity vs. sedentary time: independent associations with adiposity in children**. *Pediatric Obesity* 2012, **7**(3):251-258.
138. Owen N, Salmon J, Koohsari MJ, Turrell G, Giles-Corti B: **Sedentary behaviour and health: mapping environmental and social contexts to underpin chronic disease prevention**. *British journal of sports medicine* 2014, **48**(3):174-177.
139. Tremblay MS, LeBlanc AG, Janssen I, Kho ME, Hicks A, Murumets K, Colley RC, Duggan M: **Canadian sedentary behaviour guidelines for children and youth**. *Applied Physiology, Nutrition, and Metabolism* 2011, **36**(1):59-64.
140. Marshall SJ, Biddle SJH, Gorely T, Cameron N, Murdey I: **Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis**. *International Journal of Obesity* 2004, **28**(10):1238-1246.
141. Barlow SE, Committee atE: **Expert Committee Recommendations Regarding the Prevention, Assessment, and Treatment of Child and Adolescent Overweight and Obesity: Summary Report**. *Pediatrics* 2007, **120**(Supplement 4):S164-S192.
142. Healy GN, Wijndaele K, Dunstan DW, Shaw JE, Salmon J, Zimmet PZ, Owen N: **Objectively measured sedentary time, physical activity, and metabolic risk the Australian Diabetes, Obesity and Lifestyle Study (AusDiab)**. *Diabetes Care* 2008, **31**(2):369-371.
143. Pearson N, Braithwaite R, Biddle S, Sluijs E, Atkin A: **Associations between sedentary behaviour and physical activity in children and adolescents: a meta-analysis**. *Obesity reviews* 2014.
144. Sonneville K, Gortmaker S: **Total energy intake, adolescent discretionary behaviors and the energy gap**. *International Journal of Obesity* 2008, **32**:S19-S27.
145. Epstein LH, Roemmich JN, Robinson JL, Paluch RA, Winiewicz DD, Fuerch JH, Robinson TN: **A randomized trial of the effects of reducing television viewing and computer use on body mass index in young children**. *Archives of Pediatrics and Adolescent Medicine* 2008, **162**(3):239.
146. Sisson SB, Shay CM, Broyles ST, Leyva M: **Television-viewing time and dietary quality among US children and adults**. *American Journal of Preventive Medicine* 2012, **43**(2):196-200.
147. Blundell J: **Physical activity and appetite control: can we close the energy gap?** *Nutrition Bulletin* 2011, **36**(3):356-366.
148. Carson V, Janssen I: **The mediating effects of dietary habits on the relationship between television viewing and body mass index among youth**. *Pediatric Obesity* 2012, **7**(5):391-398.
149. Dietz WH, Gortmaker SL: **Do we fatten our children at the television set? Obesity and television viewing in children and adolescents**. *Pediatrics* 1985, **75**(5):807-812.

150. Gortmaker SL, Must A, Sobol AM, Peterson K, Colditz GA, Dietz WH: **Television viewing as a cause of increasing obesity among children in the United States, 1986-1990**. *Archives of Pediatrics & Adolescent Medicine* 1996, **150**(4):356-362.
151. Swinburn B, Shelly A: **Effects of TV time and other sedentary pursuits**. *International Journal of Obesity* 2008, **32**:S132-S136.
152. Braithwaite I, Stewart AW, Hancox RJ, Beasley R, Murphy R, Mitchell EA, Group IPTS: **The worldwide association between television viewing and obesity in children and adolescents: cross sectional study**. *PLoS One* 2013, **8**(9):e74263.
153. Lane A, Harrison M, Murphy N: **Screen Time Increases Risk of Overweight and Obesity in Active and Inactive 9**. *Journal of physical activity & health* 2013.
154. Must A, Tybor D: **Physical activity and sedentary behavior: a review of longitudinal studies of weight and adiposity in youth**. *International Journal of Obesity* 2005, **29**:S84-S96.
155. Mitchell JA, Mattocks C, Ness AR, Leary SD, Pate RR, Dowda M, Blair SN, Riddoch C: **Sedentary behavior and obesity in a large cohort of children**. *Obesity* 2009, **17**(8):1596-1602.
156. Carson V, Stone M, Faulkner G: **Patterns of sedentary behavior and weight status among children**. *Pediatric Exercise Science* 2014, **26**(1):95-102.
157. Herman KM, Sabiston CM, Mathieu M-E, Tremblay A, Paradis G: **Sedentary behavior in a cohort of 8-to 10-year-old children at elevated risk of obesity**. *Preventive medicine* 2014, **60**:115-120.
158. Kwon S, Burns TL, Levy SM, Janz KF: **Which contributes more to childhood adiposity-high levels of sedentarism or low levels of moderate-through-vigorous physical activity? The Iowa Bone Development Study**. *The Journal of pediatrics* 2013, **162**(6):1169-1174.
159. Parsons TJ, Power C, Logan S, Summerbell CD: **Childhood predictors of adult obesity: A systematic review**. *Int J Obes* 1999, **23**(supplement 8):S1-S107.
160. Skelton JA, Irby MB, Grzywacz JG, Miller G: **Etiologies of obesity in children: nature and nurture**. *Pediatric Clinics of North America* 2011, **58**(6):1333-1354.
161. Hill JO, Peters JC: **Environmental contributions to the obesity epidemic**. *Science* 1998, **280**(5368):1371-1374.
162. Simonen RL, Perusse L, Rankinen T, Rice T, Rao D, Bouchard C: **Familial aggregation of physical activity levels in the Quebec Family Study**. *Medicine and science in sports and exercise* 2002, **34**(7):1137-1142.
163. Oliveria SA, Ellison RC, Moore LL, Gillman MW, Garrahie EJ, Singer MR: **Parent-child relationships in nutrient intake: the Framingham Children's Study**. *The American Journal of Clinical Nutrition* 1992, **56**(3):593-598.
164. Steffen LM, Sinaiko AR, Zhou X, Moran A, Jacobs DR, Korenfeld Y, Dengel DR, Chow LS, Steinberger J: **Relation of adiposity, television and screen time in offspring to their parents**. *BMC Pediatrics* 2013, **13**(1):133.
165. Davison K, Birch L: **Child and parent characteristics as predictors of change in girls' body mass index**. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity* 2001, **25**(12):1834.
166. Hill A, Roberts J: **Body mass index: a comparison between self-reported and measured height and weight**. *Journal of Public Health* 1998, **20**(2):206.
167. Danielzik S, Czerwinski-Mast M, Langnase K, Dilba B, Muller MJ: **Parental overweight, socioeconomic status and high birth weight are the major determinants of overweight and obesity in 5-7 y-old children: Baseline data of the Kiel Obesity Prevention Study (KOPS)**. *International Journal of Obesity* 2004, **28**(11):1494-1502.

168. Garn SM, Sullivan TV, Hawthorne VM: **Fatness and obesity of the parents of obese individuals**. *Am J Clin Nutr* 1989, **50**(6):1308-1313.
169. Burke V, Beilin L, Dunbar D: **Family lifestyle and parental body mass index as predictors of body mass index in Australian children: a longitudinal study**. *Int J Obes Relat Metab Disord* 2001, **25**(2):147.
170. Burke V, Beilin LJ, Simmer K, Oddy WH, Blake KV, Doherty D, Kendall GE, Newnham JP, Landau LI, Stanley FJ: **Predictors of body mass index and associations with cardiovascular risk factors in Australian children: A prospective cohort study**. *International Journal of Obesity* 2005, **29**(1):15-23.
171. Marild S, Bondestam M, Bergstrom R, Ehnberg S, Hollsing A, Albertsson-Wikland K: **Prevalence trends of obesity and overweight among 10-year-old children in western Sweden and relationship with parental body mass index**. *Acta Paediatrica, International Journal of Paediatrics* 2004, **93**(12):1588-1595.
172. Lazzeri G, Pammolli A, Pilato V, Giacchi MV: **Relationship between 8/9-yr-old school children BMI, parents' BMI and educational level: a cross sectional survey**. *Nutrition Journal* 2011, **10**:76.
173. Danielzik S, Langnäse K, Mast M, Spethmann C, Müller MJ: **Impact of parental BMI on the manifestation of overweight 5–7 year old children**. *Eur J Nutr* 2002, **41**(3):132-138.
174. Semmler C, Ashcroft J, Van Jaarsveld CHM, Carnell S, Wardle J: **Development of overweight in children in relation to parental weight and socioeconomic status**. *Obesity* 2009, **17**(4):814-820.
175. Whitaker KL, Jarvis MJ, Beeken RJ, Boniface D, Wardle J: **Comparing maternal and paternal intergenerational transmission of obesity risk in a large population-based sample**. *Am J Clin Nutr* 2010, **91**(6):1560-1567.
176. Wake M, Hardy P, Canterford L, Sawyer M, Carlin J: **Overweight, obesity and girth of Australian preschoolers: prevalence and socio-economic correlates**. *Int J Obes* 2006, **31**(7):1044-1051.
177. Ochoa MC, Azcona C, Moreno-Aliaga MJ, Martinez-Gonzalez MA, Martinez JA, Marti A: **Influence of parental body mass index on offspring body mass index in a Spanish population**. *Revista Espanola de Obesidad* 2009, **7**(6):395-401.
178. Garipagaoglu M, Budak N, Süt N, Akdikmen Ö, Oner N: **Obesity risk factors in Turkish children**. *Journal of Pediatric Nursing* 2009, **24**(4):332-337.
179. Magarey AM, Daniels LA, Boulton TJ, Cockington RA: **Predicting obesity in early adulthood from childhood and parental obesity**. *Int J Obes Relat Metab Disord* 2003, **27**(4):505-513.
180. Francis LA, Ventura AK, Marini M, Birch LL: **Parent overweight predicts daughters' increase in BMI and disinhibited overeating from 5 to 13 years**. *Obesity* 2007, **15**(6):1544-1553.
181. Perez-Pastor EM, Metcalf BS, Hosking J, Jeffery AN, Voss LD, Wilkin TJ: **Assortative weight gain in mother-daughter and father-son pairs: An emerging source of childhood obesity. Longitudinal study of trios (EarlyBird 43)**. *International Journal of Obesity* 2009, **33**(7):727-735.
182. Pomerleau J, McKee M (Eds.): *Issues in Public Health*. Berkshire: Open University Press; 2009.
183. Shrewsbury V, Wardle J: **Socioeconomic Status and Adiposity in Childhood: A Systematic Review of Cross-sectional Studies 1990-2005**. *Obesity* 2008, **16**(2):275-284.
184. Moschonis G, Tanagra S, Vandorou A, Kyriakou AE, Dede V, Siatitsa PE, Koumpitski A, Androutsos O, Grammatikaki E, Kantilafti M *et al*: **Social, economic and demographic correlates of overweight and obesity in primary-school children:**

preliminary data from the Healthy Growth Study. *Public Health Nutrition* 2010, **13**(10 A):1693-1700.
185. Pickett KE, Kelly S, Brunner E, Lobstein T, Wilkinson RG: **Wider income gaps, wider waistbands? An ecological study of obesity and income inequality**. *Journal of Epidemiology and Community Health* 2005, **59**(8):670-674.
186. Giskes K, Avendaňo M, Brug J, Kunst A: **A systematic review of studies on socioeconomic inequalities in dietary intakes associated with weight gain and overweight/obesity conducted among European adults**. *Obesity reviews* 2010, **11**(6):413-429.
187. Cummins S, Macintyre S: **Food environments and obesity—neighbourhood or nation?** *International Journal of Epidemiology* 2006, **35**(1):100-104.
188. Singh GK, Siahpush M, Kogan MD: **Rising social inequalities in US childhood obesity, 2003-2007**. *Annals of epidemiology* 2010, **20**(1):40-52.
189. Stamatakis E, Wardle J, Cole TJ: **Childhood obesity and overweight prevalence trends in England: evidence for growing socioeconomic disparities**. *International Journal of Obesity* 2010, **34**(1):41-47.
190. Wang Y: **Cross-national comparison of childhood obesity: the epidemic and the relationship between obesity and socioeconomic status**. *International Journal of Epidemiology* 2001, **30**(5):1129-1136.
191. Bammann K, Gwozdz W, Lanfer A, Barba G, De Henauw S, Eiben G, Fernandez-Alvira J, Kovacs E, Lissner L, Moreno L: **Socioeconomic factors and childhood overweight in Europe: results from the multi-centre IDEFICS study**. *Pediatric Obesity* 2013, **8**(1):1-12.
192. Blackman T: *Placing Health: neighbourhood renewal, health improvement and complexity*. Bristol: The Policy Press; 2006.
193. Papas MA, Alberg AJ, Ewing R, Helzlsouer KJ, Gary TL, Klassen AC: **The built environment and obesity**. *Epidemiologic Reviews* 2007, **29**(1):129-143.
194. French SA, Story M, Jeffery RW: **Environmental influences on eating and physical activity**. *Annual review of public health* 2001, **22**(1):309-335.
195. Mackenbach JD, Rutter H, Compernolle S, Glonti K, Oppert J-M, Charreire H, De Bourdeaudhuij I, Brug J, Nijpels G, Lakerveld J: **Obesogenic environments: a systematic review of the association between the physical environment and adult weight status, the SPOTLIGHT project**. *BMC Public Health* 2014, **14**(1):233.
196. Gordon-Larsen P, Nelson MC, Page P, Popkin BM: **Inequality in the built environment underlies key health disparities in physical activity and obesity**. *Pediatrics* 2006, **117**(2):417-424.
197. White M: **Food access and obesity**. *Obesity reviews* 2007, **8**(s1):99-107.
198. Friel S, Walsh O, McCarthy D: **The irony of a rich country: issues of financial access to and availability of healthy food in the Republic of Ireland**. *Journal of Epidemiology and Community Health* 2006, **60**(12):1013-1019.
199. Lee A, Mhurchu CN, Sacks G, Swinburn B, Snowdon W, Vandevijvere S, Hawkes C, L'abbé M, Rayner M, Sanders D: **Monitoring the price and affordability of foods and diets globally**. *Obesity reviews* 2013, **14**(S1):82-95.
200. Gearhart R, Gruber DM, Vanata DF: **Obesity in the lower socio-economic status segments of American society**. In *The Forum on Public Policy: 2008*; 2008.
201. Cummins S, Macintyre S: **“Food deserts”—evidence and assumption in health policy making**. *BMJ* 2002, **325**(7361):436-438.
202. Holsten JE: **Obesity and the community food environment: a systematic review**. *Public health nutrition* 2009, **12**(03):397-405.
203. Friel S, Harrington J, Thunhurst C: **Standard of Healthy Living on the Island of Ireland**. *Ireland: Food Safety Promotion Board* 2005.

204. McCormack D, Seery S, Cullen M: **Examination of the cost of healthy eating and specialised diets for a single individual in Ireland 2013 Update**. Irish Nutrition and Dietetic Institute.; 2013.
205. Layte R, Harrington J, Sexton E, Perry IJ, Cullinan J, Lyons S: **Irish exceptionalism? local food environments and dietary quality**. *J Epidemiol Community Health* 2011, **65**(10):881-888.
206. Dowler E: **Food poverty and food policy**. *IDS Bulletin* 1998, **29**(1):58-65.
207. Friel S, Conlon C: **Food Poverty and Policy**. 2004.
208. Black C, Moon G, Baird J: **Dietary inequalities: What is the evidence for the effect of the neighbourhood food environment?** *Health & place* 2013.
209. Block JP, Scribner RA, DeSalvo KB: **Fast food, race/ethnicity, and income: a geographic analysis**. *American Journal of Preventive Medicine* 2004, **27**(3):211-217.
210. Morland K, Wing S, Diez Roux A, Poole C: **Neighborhood characteristics associated with the location of food stores and food service places**. *American Journal of Preventive Medicine* 2002, **22**(1):23-29.
211. Gibson DM: **The neighborhood food environment and adult weight status: estimates from longitudinal data**. *American journal of public health* 2011, **101**(1):71-78.
212. Morland KB, Evenson KR: **Obesity prevalence and the local food environment**. *Health & place* 2009, **15**(2):491-495.
213. Spence JC, Cutumisu N, Edwards J, Raine KD, Smoyer-Tomic K: **Relation between local food environments and obesity among adults**. *BMC Public Health* 2009, **9**(1):192.
214. Powell LM, Han E, Chaloupka FJ: **Economic contextual factors, food consumption, and obesity among US adolescents**. *The Journal of nutrition* 2010, **140**(6):1175-1180.
215. Caspi CE, Sorensen G, Subramanian S, Kawachi I: **The local food environment and diet: a systematic review**. *Health & place* 2012, **18**(5):1172-1187.
216. Mason KE, Bentley RJ, Kavanagh AM: **Fruit and vegetable purchasing and the relative density of healthy and unhealthy food stores: evidence from an Australian multilevel study**. *Journal of Epidemiology and Community Health* 2013, **67**(3):231-236.
217. Simmons D, McKenzie A, Eaton S, Cox N, Khan MA, Shaw J, Zimmet P: **Choice and availability of takeaway and restaurant food is not related to the prevalence of adult obesity in rural communities in Australia**. *International Journal of Obesity* 2005, **29**(6):703-710.
218. Morgen CS, Rokholm B, Brixval CS, Andersen CS, Andersen LG, Rasmussen M, Andersen A-MN, Due P, Sørensen TI: **Trends in Prevalence of Overweight and Obesity in Danish Infants, Children and Adolescents–Are We Still on a Plateau?** *PLoS One* 2013, **8**(7):e69860.
219. Bergström E, Blomquist HKs: **Is the prevalence of overweight and obesity declining among 4-year-old Swedish children?** *Acta Pædiatrica* 2009, **98**(12):1956-1958.
220. Olds T, Maher C, Zumin S, Péneau S, Lioret S, Castetbon K, WILDE J, Hohepa M, Maddison R, Lissner L: **Evidence that the prevalence of childhood overweight is plateauing: data from nine countries**. *International Journal of Pediatric Obesity* 2011, **6**(5-6):342-360.
221. Perry IJ, Whelton H, Harrington J, Cousins B: **The heights and weights of Irish children from the post-war era to the Celtic tiger**. *Journal of Epidemiology and Community Health* 2009, **63**(3):262-264.

222. Heavey P, McGloin A, Kilroe J, Daly L, O'Mahony D, Kelleher C: **Childhood Obesity Surveillance Initiative in Ireland. Main Report.** . Dublin: Health Service Executive and Department of Health and Children; 2009.
223. Heinen MM, Murrin C, Daly L, O'Brien J, Heavey P, Kilroe J, O'Brien M, Scully H, Mulhern LM, Lynam A *et al*: **The Childhood Obesity Surveillance Initiative (COSI) in the Republic of Ireland: Findings from 2008, 2010 and 2012.** Dublin: Health Service Executive; 2014.
224. Radulescu M, Diepgen TL, Weisshaar E, Williams H: *What makes a good prevalence survey*. 2nd edition. Oxford: Blackwell Publishing; 2009.
225. Vidmar S, Carlin J, Hesketh K, Cole T: **Standardizing anthropometric measures in children and adolescents with new functions for egen**. *Stata J* 2004, **4**(1):50-55.
226. Meath. H: **Oral health survey of 12 year old children in Meath, 2009. Internal report, (unpublished data)**.
227. Whelton H, Harrington J, Crowley E, Kelleher V, Cronin M, IJ. P: **North South Survey of children's Height, Weight and Body Mass Index, 2002**. Edited by Children DoHa. Dublin: Department of Health and Children; 2006.
228. Williams J, Greene S, Doyle E, Harris E, Layte R, McCoy R: **Growing Up in Ireland. The Lives of 9-Year-Olds. Report 1**. Dublin, Ireland: Office of the Minister for Children and Youth Affairs; 2009.
229. Whelton H, Harrington J, Crowley E, Kelleher V, Cronin M, Perry IJ: **Prevalence of overweight and obesity on the island of Ireland: results from the North South Survey of Children's Height, Weight and Body Mass Index, 2002**. *BMC Public Health* 2007, **7**:187-187.
230. Wabitsch M, Moss A, Kromeyer-Hauschild K: **Unexpected plateauing of childhood obesity rates in developed countries**. *BMC Medicine* 2014, **12**(1):17.
231. Wright CM, Emmett PM, Ness AR, Reilly JJ, Sherriff A: **Tracking of obesity and body fatness through mid-childhood**. *Archives of Disease in Childhood -- Fetal & Neonatal Edition* 2010, **95**(8):8-8.
232. Harrison M, Burns CF, McGuinness M, Heslin J, Murphy NM: **Influence of a health education intervention on physical activity and screen time in primary school children:'Switch Off–Get Active'**. *Journal of Science and Medicine in Sport* 2006, **9**(5):388-394.
233. Hollywood E, Comiskey C, Begley T, Snel A, O'Sullivan K, Quirke M, Wynne C: **Measuring and modelling body mass index among a cohort of urban children living with disadvantage**. *Journal of Advanced Nursing* 2013, **69**(4):851-861.
234. De Brún A, McKenzie K, McCarthy M, McGloin A: **The Emergence and Portrayal of Obesity in The Irish Times: Content Analysis of Obesity Coverage, 1997–2009**. *Health Communication* 2012, **27**(4):389-398.
235. Department of Health and Children: **Obesity: The Policy Challenges –The Report of the National Taskforce on Obesity 2005**. Department of Health and Children; 2005.
236. Rose G: **Sick individuals and sick populations**. *International Journal of Epidemiology* 2001, **30**(3):427-432.
237. O'Malley G, Clarke M, Burls A, Murphy S, Murphy N, Perry IJ: **A smartphone intervention for adolescent obesity: study protocol for a randomised controlled non-inferiority trial**. *Trials* 2014, **15**(1):43.
238. Horne P, Hardman C, Lowe C, Tapper K, Le Noury J, Madden P, Patel P, Doody M: **Increasing parental provision and children's consumption of lunchbox fruit and vegetables in Ireland: the Food Dudes intervention**. *European Journal of Clinical Nutrition* 2009, **63**(5):613-618.

239. Murtagh E, Mulvihill M, Markey O: **Bizzy Break! The effect of a classroom-based activity break on in-school physical activity levels of primary school children**. *Pediatric Exercise Science* 2013, **25**(2):300.
240. Brug J, van Stralen MM, te Velde SJ, Chinapaw MJ, De Bourdeaudhuij I, Lien N, Bere E, Maskini V, Singh AS, Maes L: **Differences in weight status and energy-balance related behaviors among schoolchildren across Europe: the ENERGY-project**. *PLoS One* 2012, **7**(4):e34742.
241. Brug J, van Stralen MM, ChinApaw MJM, De Bourdeaudhuij I, Lien N, Bere E, Singh AS, Maes L, Moreno L, Jan N *et al*: **Differences in weight status and energy-balance related behaviours according to ethnic background among adolescents in seven countries in Europe: the ENERGY-project**. *Pediatric Obesity* 2012, **7**(5):399-411.
242. Layte R, McCrory C: **Growing Up in Ireland–Overweight and Obesity among 9-year-olds**. Ireland, Dublin: Department of Children and Youth Affairs; 2011.
243. McMaster C, Cullen L, Raymond N: **Overweight and obesity in Irish primary schools: Retrospective cohort study**. *Child: Care, Health and Development* 2005, **31**(5):499-506.
244. Evans DS, Glacken M: **Measuring height and weight in school children as a public health indicator/Marita Glacken, David Evans**. *-4024* 2006.
245. Barron C, Comiskey C, Saris J: **Prevalence rates and comparisons of obesity levels in Ireland**. *British journal of nursing (Mark Allen Publishing)* 2009, **18**(13):799-803.
246. Murrin CM, Kelly GE, Tremblay RE, Kelleher CC: **Body mass index and height over three generations: evidence from the Lifeways cross-generational cohort study**. *BMC Public Health* 2012, **12**(1):81.
247. O'Mahony D, Fallon U, Hannon F, Kloeckner K, Avalos G, Murphy A, Kelleher C: **The Lifeways Cross-Generation Study: design, recruitment and data management considerations**. *Irish Medical Journal* 2007, **100**(8):suppl 3.
248. Belton S, Brady P, Meegan S, Woods C: **Pedometer step count and BMI of Irish primary school children aged 6–9 years**. *Preventive medicine* 2010, **50**(4):189-192.
249. Fitzgerald A: **Psychological and social factors in predicting children's food choices: The development of a theoretical model.** In *PhD thesis*. Galway; 2010.
250. Glacken M, Evans DS: **Measuring Height and Weight in School Children As a Public Health Indicator**. Galway, Ireland: Department of Public Health, Health Services Executive West, ; 2006.
251. Malik VS, Willett WC, Hu FB: **Global obesity: trends, risk factors and policy implications**. *Nature Reviews Endocrinology* 2012, **9**(1):13-27.
252. Ang Y, Wee B, Poh B, Ismail M: **Multifactorial Influences of Childhood Obesity**. *Current Obesity Reports* 2013, **2**(1):10-22.
253. Kleiser C, Schaffrath Rosario A, Mensink GB, Prinz-Langenohl R, Kurth BM: **Potential determinants of obesity among children and adolescents in Germany: results from the cross-sectional KiGGS Study**. *BMC Public Health* 2009, **9**:46.
254. Newby P: **Are dietary intakes and eating behaviors related to childhood obesity? A comprehensive review of the evidence**. *The Journal of Law, Medicine & Ethics* 2007, **35**(1):35-60.
255. Dunton GF, Kaplan J, Wolch J, Jerrett M, Reynolds KD: **Physical environmental correlates of childhood obesity: a systematic review**. *Obesity reviews* 2009, **10**(4):393-402.
256. Pate R, O'Neill J, Liese A, Janz K, Granberg E, Colabianchi N, Harsha D, Condrasky M, O'Neil P, Lau E: **Factors associated with development of excessive fatness in children and adolescents: a review of prospective studies**. *Obesity reviews* 2013, **14**:645-658.

257. van Sluijs EM, Skidmore PM, Mwanza K, Jones AP, Callaghan AM, Ekelund U: **Physical activity and dietary behaviour in a population-based sample of British 10-year old children: the SPEEDY study (Sport, Physical activity and Eating behaviour Environmental Determinants in Young people)**. *BMC Public Health* 2008, **8**:388.
258. Van der Horst K, Oenema A, Ferreira I, Wendel-Vos W, Giskes K, Van Lenthe F, Brug J: **A systematic review of environmental correlates of obesity-related dietary behaviors in youth**. *Health education research* 2007, **22**(2):203-226.
259. Brown IJ, Tzoulaki I, Candeias V, Elliott P: **Salt intakes around the world: Implications for public health**. *International Journal of Epidemiology* 2009, **38**(3):791-813.
260. Grimes CA, Campbell KJ, Riddell LJ: **Sources of sodium in Australian children's diets and the effect of the application of sodium targets to food products to reduce sodium intake**. *The British Journal of Nutrition* 2011, **105**(3):468-477.
261. Perry IJ, Browne G, Loughrey M, Harrington J, Lutomski J, Fitzgerald A: **Dietary salt intake and related risk factors in the Irish population. A report for safefood**. 2010.
262. He FJ, Marrero NM, MacGregor GA: **Salt and blood pressure in children and adolescents**. *Journal of Human Hypertension* 2008, **22**(1):4-11.
263. He FJ, Marrero NM, MacGregor GA: **Salt Intake Is Related to Soft Drink Consumption in Children and Adolescents: A Link to Obesity?** *Hypertension* 2008, **51**(3):629-634.
264. Cooke L: **The importance of exposure for healthy eating in childhood: a review**. *Journal of Human Nutrition and Dietetics* 2007, **20**(4):294-301.
265. Bao W, Threefoot SA, Srinivasan SR, Berenson GS: **Essential hypertension predicted by tracking of elevated blood pressure from childhood to adulthood: the Bogalusa Heart Study**. *American journal of hypertension* 1995, **8**(7):657-665.
266. **Department of Education and Skills** [http://www.education.ie/en/]
267. Rice W: **Nutritional Health Friendliness of Cork City Primary Schools**. Masters in Public Health thesis, University College Cork, Department of Epidemiology and Public Health; 2008.
268. **Growing Up in Australia: The Longitudinal Study of Australian Children 2010–11 Annual Report**. Australian Government Department of Families, Housing, Community Services and Indigenous Affairs; 2012.
269. **CHASE: Child Heart & Health Study in England** [http://www.chasestudy.ac.uk/study-measurement]
270. Kowalski KC, Crocker PRE, Donen RM, Honours B: **The physical activity questionnaire for older children (PAQ-C) and adolescents (PAQ-A) manual**. Saskatchewan: College of Kinesiology, University of Saskatchewan; 2004.
271. Harrington J, Perry I, Lutomski J, Morgan K, McGee H, Shelley E, Watson D, Barry M: **SLÁN 2007: Survey of Lifestyle, Attitudes and Nutrition in Ireland. Dietary Habits of the Irish Population**. Ireland, Dublin: Department of Health and Children; 2008.
272. Fraser A, Macdonald-Wallis C, Tilling K, Boyd A, Golding J, Smith GD, Henderson J, Macleod J, Molloy L, Ness A: **Cohort profile: the Avon Longitudinal Study of Parents and Children: ALSPAC mothers cohort**. *International Journal of Epidemiology* 2013, **42**(1):97-110.
273. Whelton H, Crowley E, O'Mullane D, Cronin M, Kelleher V: **Children's oral health in Ireland 2002: preliminary results**. Ireland, Dublin: Department of Health and Children; 2003.
274. Larson NI, Neumark-Sztainer D, Hannan PJ, Story M: **Family meals during adolescence are associated with higher diet quality and healthful meal patterns during young adulthood**. *Journal of the American Dietetic Association* 2007, **107**(9):1502-1510.

275. Kearney PM, Harrington JM, Mc Carthy VJ, Fitzgerald AP, Perry IJ: **Cohort Profile: The Cork and Kerry Diabetes and Heart Disease Study**. *International Journal of Epidemiology* 2012:1-10.
276. **Central Statisics Office** [http://www.cso.ie/en/index.html]
277. Birch LL, Fisher JO, Grimm-Thomas K, Markey CN, Sawyer R, Johnson SL: **Confirmatory factor analysis of the Child Feeding Questionnaire: a measure of parental attitudes, beliefs and practices about child feeding and obesity proneness**. *Appetite* 2001, **36**(3):201-210.
278. Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth M, Ainsworth B, Pratt M, Ekelund U, Yngve A, Sallis J *et al*: **International physical activity questionnaire: 12-country reliability and validity**. *Medicine & Science in Sports & Exercise* 2003, **35**:1381-1395.
279. Tennant R, Hiller L, Fishwick R, Platt S, Joseph S, Weich S, Parkinson J, Secker J, Stewart-Brown S: **The Warwick-Edinburgh Mental Well-being Scale (WEMWBS): development and UK validation**. *Health and quality of life outcomes* 2007, **5**:63.
280. Foster E, Hawkins A, Adamson A: **Young Person's Food Atlas Primary**. London: Food Standards Agency.
281. Esliger DW, Rowlands AV, Hurst TL, Catt M, Murray P, Eston RG: **Validation of the GENEA Accelerometer**. *Medicine & Science in Sports & Exercise* 2011, **43**(6):1085.
282. Phillips LRS, Parfitt G, Rowlands AV: **Calibration of the GENEA accelerometer for assessment of physical activity intensity in children**. *Journal of Science and Medicine in Sport* 2012, **16**(2):124-128.
283. Welch WA, Bassett DR, Thompson DL, Freedson PS, Staudenmayer JW, John D, Steeves JA, Conger SA, Ceaser T, Howe CA: **Classification Accuracy of the Wrist-Worn GENEA Accelerometer**. *Medicine and science in sports and exercise* 2013, **45**(10):2012-2019.
284. Harrington KF, Binkley D, Reynolds KD, Duvall RC, Copeland JR, Franklin F, Raczynski J: **Recruitment issues in school-based research: lessons learned from the High 5 Alabama Project**. *Journal of School Health* 1997, **67**(10):415-421.
285. Kristjansson AL, Sigfusson J, Sigfusdottir ID, Allegrante JP: **Data Collection Procedures for School-Based Surveys Among Adolescents: The Youth in Europe Study**. *Journal of School Health* 2013, **83**(9):662-667.
286. White D, Morris A, Hill K, Bradnock G: **Consent and school-based surveys**. *British dental journal* 2007, **202**(12):715.
287. Hallfors D, Iritani B: **Local and State School-Based Substance Use Surveys Availability, Content, and Quality**. *Evaluation Review* 2002, **26**(4):418-437.
288. Topouchian JA, El Assaad MA, Orobinskaia LV, El Feghali RN, Asmar RG: **Validation of two automatic devices for self-measurement of blood pressure according to the International Protocol of the European Society of Hypertension: the Omron M6 (HEM-7001-E) and the Omron R7 (HEM 637-IT)**. *Blood pressure monitoring* 2006, **11**(3):165.
289. Stergiou GS, Yiannes NG, Rarra VC: **Validation of the Omron 705 IT oscillometric device for home blood pressure measurement in children and adolescents: the Arsakion School Study**. *Blood pressure monitoring* 2006, **11**(4):229-234.
290. Craigie AM, Lake AA, Kelly SA, Adamson AJ, Mathers JC: **Tracking of obesity-related behaviours from childhood to adulthood: a systematic review**. *Maturitas* 2011, **70**(3):266-284.
291. Ebbeling CB, Pawlak DB, Ludwig DS: **Childhood obesity: public-health crisis, common sense cure**. *The Lancet* 2002, **360**(9331):473-482.
292. Hoffmann I: **Transcending reductionism in nutrition research**. *The American journal of clinical nutrition* 2003, **78**(3):514S-516S.

293. Lazarou C, Newby PK: **Use of dietary indexes among children in developed countries**. *Advances in nutrition (Bethesda, Md)* 2011, **2**(4):295-303.
294. Marshall S, Burrows T, Collins C: **Systematic review of diet quality indices and their associations with health-related outcomes in children and adolescents**. *Journal of Human Nutrition and Dietetics* 2014.
295. Karanja NM, Obarzanek E, Lin PH, McCullough ML, Phillips KM, Swain JF, Champagne CM, Hoben KP: **Descriptive characteristics of the dietary patterns used in the Dietary Approaches to Stop Hypertension Trial. DASH Collaborative Research Group**. *J Am Diet Assoc* 1999, **99**(8 Suppl):S19-27.
296. Sacks FM, Obarzanek E, Windhauser MM, Svetkey LP, Vollmer WM, McCullough M, Karanja N, Lin PH, Steele P, Proschan MA *et al*: **Rationale and design of the Dietary Approaches to Stop Hypertension trial (DASH). A multicenter controlled-feeding study of dietary patterns to lower blood pressure**. *Annals of epidemiology* 1995, **5**(2):108-118.
297. Ma J, Strub P, Lavori PW, Buist AS, Camargo CA, Jr., Nadeau KC, Wilson SR, Xiao L: **DASH for asthma: a pilot study of the DASH diet in not-well-controlled adult asthma**. *Contemporary clinical trials* 2013, **35**(2):55-67.
298. Fung TT, Chiuve SE, McCullough ML, Rexrode KM, Logroscino G, Hu FB: **Adherence to a DASH-style diet and risk of coronary heart disease and stroke in women**. *Archives of internal medicine* 2008, **168**(7):713-720.
299. Fung TT, Hu FB, Wu K, Chiuve SE, Fuchs CS, Giovannucci E: **The Mediterranean and Dietary Approaches to Stop Hypertension (DASH) diets and colorectal cancer**. *The American journal of clinical nutrition* 2010, **92**(6):1429-1435.
300. Berz JP, Singer MR, Guo X, Daniels SR, Moore LL: **Use of a DASH food group score to predict excess weight gain in adolescent girls in the National Growth and Health Study**. *Archives of pediatrics & adolescent medicine* 2011, **165**(6):540-546.
301. Novotny R, Nigg C, McGlone K, Renda G, Jung N, Matsunaga M, Karanja N: **Pacific Tracker 2 - expert system (PacTrac2-ES) behavioural assessment and intervention tool for the Pacific Kids DASH for Health (PacDASH) study**. *Food chemistry* 2013, **140**(3):471-477.
302. Van Horn L, Vincent E: **The CHILD 1 and DASH diets: rationale and translational applications**. *Pediatric annals* 2013, **42**(9):372-374.
303. Flynn MA, O'Brien CM, Faulkner G, Flynn CA, Gajownik M, Burke SJ: **Revision of food-based dietary guidelines for Ireland, Phase 1: evaluation of Ireland's food guide**. *Public health nutrition* 2011, **15**(3):518.
304. Flynn MA, O'Brien CM, Faulkner G, Flynn CA, Gajownik M, Burke SJ: **Revision of food-based dietary guidelines for Ireland, Phase 1: evaluation of Ireland's food guide**. *Public health nutrition* 2012, **15**(03):518-526.
305. Lyons J, Walton J, Flynn A: **Development of an online database of typical food portion sizes in Irish population groups**. *Journal of nutritional science* 2013, **2**:e25.
306. Lyons J, Giltinan M: **The Irish Food Portion Sizes Database, First Edition**. University College Cork; 2013.
307. Food Standards Agency: **McCance and Widdowson's The Composition of Foods: Royal Society of Chemistry**. 2014.
308. Black LJ, Ireland J, Møller A, Roe M, Walton J, Flynn A, Finglas PM, Kiely M: **Development of an on-line Irish food composition database for nutrients**. *Journal of Food Composition & Analysis* 2011, **24**(7):1017-1023.
309. Hu FB: **Resolved: there is sufficient scientific evidence that decreasing sugar-sweetened beverage consumption will reduce the prevalence of obesity and obesity-related diseases**. *Obes Rev* 2013, **14**(8):606-619.

310. Freeland-Graves JH, Nitzke S: **Position of the academy of nutrition and dietetics: total diet approach to healthy eating**. *Journal of the Academy of Nutrition and Dietetics* 2013, **113**(2):307-317.
311. Schofield W: **Predicting basal metabolic rate, new standards and review of previous work**. *Human nutrition Clinical nutrition* 1984, **39**:5-41.
312. Goldberg G, Black A, Jebb S, Cole T, Murgatroyd P, Coward W, Prentice A: **Critical evaluation of energy intake data using fundamental principles of energy physiology: 1. Derivation of cut-off limits to identify under-recording**. *European Journal of Clinical Nutrition* 1991, **45**(12):569-581.
313. Black AE: **Critical evaluation of energy intake using the Goldberg cut-off for energy intake: basal metabolic rate. A practical guide to its calculation, use and limitations**. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity* 2000, **24**(9):1119-1130.
314. World Health Organization: *Global recommendations on physical activity for health*: World Health Organization; 2010.
315. Barros AJ, Hirakata VN: **Alternatives for logistic regression in cross-sectional studies: an empirical comparison of models that directly estimate the prevalence ratio**. *BMC medical research methodology* 2003, **3**(1):21.
316. McNutt L-A, Wu C, Xue X, Hafner JP: **Estimating the relative risk in cohort studies and clinical trials of common outcomes**. *American Journal of Epidemiology* 2003, **157**(10):940-943.
317. Lioret S, Touvier M, Balin M, Huybrechts I, Carine D, Dufour A, Bertin M, Marie B, Lafay L: **Characteristics of energy under-reporting in children and adolescents**. *British Journal of Nutrition* 2011, **105**:1671-1680.
318. Van Der Horst K, Oenema A, Ferreira I, Wendel-Vos W, Giskes K, Van Lenthe F, Brug J: **A systematic review of environmental correlates of obesity-related dietary behaviors in youth**. *Health education research* 2007, **22**(2):203.
319. Leech RM, McNaughton SA, Timperio A: **The clustering of diet, physical activity and sedentary behavior in children and adolescents: a review**. *Int J Behav Nutr Phys Act* 2014, **11**(4).
320. Harrington J, Fitzgerald AP, Layte R, Lutomski J, Molcho M, Perry IJ: **Sociodemographic, health and lifestyle predictors of poor diets**. *Public Health Nutrition* 2011, **1**(1):1-10.
321. Mytton O, Gray A, Rayner M, Rutter H: **Could targeted food taxes improve health?** *Journal of Epidemiology and Community Health* 2007, **61**(8):689-694.
322. Mytton O, Gray A, Rayner M, Rutter H: **Could targeted food taxes improve health?** *Journal of Epidemiology & Community Health* 2007, **61**(8):689-694.
323. Hajna S, Liu J, LeBlanc PJ, Faught BE, Merchant AT, Cairney J, Hay J: **Association between body composition and conformity to the recommendations of Canada's Food Guide and the Dietary Approaches to Stop Hypertension (DASH) diet in peri-adolescence**. *Public health nutrition* 2012, **15**(10):1890-1896.
324. Farajian P, Risvas G, Karasouli K, Pounis GD, Kastorini CM, Panagiotakos DB, Zampelas A: **Very high childhood obesity prevalence and low adherence rates to the Mediterranean diet in Greek children: The GRECO study**. *Atherosclerosis* 2011, **217**(2):525-530.
325. Golley RK, Hendrie GA, McNaughton SA: **Scores on the dietary guideline index for children and adolescents are associated with nutrient intake and socio-economic position but not adiposity**. *The Journal of nutrition* 2011, **141**(7):1340-1347.
326. Cavill N, Kahlmeier S, Racioppi F: *Physical activity and health in Europe: evidence for action*: World Health Organization; 2006.

327. Brage S, Wedderkopp N, Ekelund U, Franks PW, Wareham NJ, Andersen LB, Froberg K: **Features of the Metabolic Syndrome Are Associated With Objectively Measured Physical Activity and Fitness in Danish Children The European Youth Heart Study (EYHS)**. *Diabetes Care* 2004, **27**(9):2141-2148.
328. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O: **Physical activity from childhood to adulthood: a 21-year tracking study**. *American Journal of Preventive Medicine* 2005, **28**(3):267-273.
329. Kelder SH, Perry CL, Klepp K-I, Lytle LL: **Longitudinal tracking of adolescent smoking, physical activity, and food choice behaviors**. *American journal of public health* 1994, **84**(7):1121-1126.
330. Dumith SC, Gigante DP, Domingues MR, Kohl HW: **Physical activity change during adolescence: a systematic review and a pooled analysis**. *International Journal of Epidemiology* 2011, **40**(3):685-698.
331. Sullivan S: **The physical activity of children: a study of 1,602 Irish schoolchildren aged 11-12 years**. *Irish Medical Journal* 2002, **95**(3):78-81.
332. Sallis JF, Prochaska JJ, Taylor WC: **A review of correlates of physical activity of children and adolescents**. *Medicine & Science in Sports & Exercise* 2000, **32**(5):963.
333. World Health Organization: **Global Strategy on Diet, Physical Activity and Health**. 2004.
334. Department of Health and Children HSE: **Get Ireland Active: The National Guidelines on Physical Activity for Ireland**. 2009.
335. Craig R, Mindell J, Hirani V: **Health Survey for England-2008: Physical Activity and Fitness, Summary of Key Findings**. *The Health and Social Care Infromation Centre* 2009:1-21.
336. Riddoch CJ, Andersen LB, Wedderkopp N, Harro M, Klasson-Heggebo L, Sardinha LB, Cooper AR, Ekelund U: **Physical activity levels and patterns of 9-and 15-yr-old European children**. *Medicine and science in sports and exercise* 2004, **36**(1):86-92.
337. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M: **Physical activity in the United States measured by accelerometer**. *Medicine and science in sports and exercise* 2008, **40**(1):181.
338. Spence JC, Lee RE: **Toward a comprehensive model of physical activity**. *Psychology of sport and exercise* 2003, **4**(1):7-24.
339. Bronfenbrenner U: **Ecological models of human development**. *Readings on the development of children* 1997, **5**.
340. Sallis JF, Owen N, Fisher EB: **Ecological models of health behavior**. *Health behavior and health education: Theory, research, and practice* 2008, **4**:465-486.
341. Van der Horst K, Paw M, Twisk JW, Van Mechelen W: **A brief review on correlates of physical activity and sedentariness in youth**. *Medicine and science in sports and exercise* 2007, **39**(8):1241.
342. Sallis JF, Story M, Lou D: **Study designs and analytic strategies for environmental and policy research on obesity, physical activity, and diet: recommendations from a meeting of experts**. *American Journal of Preventive Medicine* 2009, **36**(2):S72-S77.
343. Irish Social Sciences Data Archive: **Sample design and response in wave 1 of the nine-year cohort of Growing Up in Ireland.**; 2010.
344. Murray A, McCrory C, Thornton M, Williams J, Quail A, Swords L, Doyle E, Harris E: **Growing Up in Ireland: Design, instrumentation and procedures for the child cohort**. Ireland, Dublin: Department of Health and Children; 2011.
345. Godin G, Shephard RJ: **A simple method to assess exercise behavior in the community**. *Canadian journal of applied sport sciences Journal canadien des sciences appliquees au sport* 1985, **10**(3):141-146.

346. Godin G, Jobin J, Bouillon J: **Assessment of leisure time exercise behavior by self-report: a concurrent validity study**. *Canadian journal of public health Revue canadienne de sante publique* 1985, **77**(5):359-362.
347. Sallis JF, Buono MJ, Roby JJ, Micale FG, Nelson JA: **Seven-day recall and other physical activity self-reports in children and adolescents**. *Medicine and science in sports and exercise* 1993, **25**(1):99-108.
348. Gordon-Larsen P, McMurray RG, Popkin BM: **Determinants of adolescent physical activity and inactivity patterns**. *Pediatrics* 2000, **105**(6):e83-e83.
349. Biddle SJ, Whitehead SH, O Donovan TM, Nevill ME: **Correlates of participation in physical activity for adolescent girls: A systematic review of recent literature**. *Journal of physical activity & health* 2005, **2**(4):423.
350. Kjønniksen L, Anderssen N, Wold B: **Organized youth sport as a predictor of physical activity in adulthood**. *Scandinavian journal of medicine & science in sports* 2009, **19**(5):646-654.
351. Melkevik O, Torsheim T, Iannotti RJ, Wold B: **Is spending time in screen-based sedentary behaviors associated with less physical activity: a cross national investigation**. 2010.
352. Vandewater EA, Shim M-s, Caplovitz AG: **Linking obesity and activity level with children's television and video game use**. *Journal of Adolescence* 2004, **27**(1):71-85.
353. Salmon J, Tremblay MS, Marshall SJ, Hume C: **Health risks, correlates, and interventions to reduce sedentary behavior in young people**. *American Journal of Preventive Medicine* 2011, **41**(2):197-206.
354. Sallis JF, Glanz K: **The role of built environments in physical activity, eating, and obesity in childhood**. *The future of children* 2006, **16**(1):89-108.
355. Hills AP, Andersen LB, Byrne NM: **Physical activity and obesity in children**. *British journal of sports medicine* 2011, **45**(11):866-870.
356. Wittmeier KDM, Mollard RC, Kriellaars DJ: **Physical Activity Intensity and Risk of Overweight and Adiposity in Children**. *Obesity* 2008, **16**(2):415-420.
357. Carson V, Janssen I: **Volume, patterns, and types of sedentary behavior and cardio-metabolic health in children and adolescents: a cross-sectional study**. *BMC Public Health* 2011, **11**(1):274.
358. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N: **Physiological and health implications of a sedentary lifestyle**. *Applied Physiology, Nutrition, and Metabolism* 2010, **35**(6):725-740.
359. Eisenmann JC, Bartee RT, Smith D, Welk G, Fu Q: **Combined influence of physical activity and television viewing on the risk of overweight in US youth**. *International Journal of Obesity* 2008, **32**(4):613-618.
360. Laurson KR, Eisenmann JC, Welk GJ, Wickel EE, Gentile DA, Walsh DA: **Combined influence of physical activity and screen time recommendations on childhood overweight**. *The Journal of pediatrics* 2008, **153**(2):209-214.
361. Jakes R, Day N, Khaw K, Luben R, Oakes S, Welch A, Bingham S, Wareham N: **Television viewing and low participation in vigorous recreation are independently associated with obesity and markers of cardiovascular disease risk: EPIC-Norfolk population-based study**. *European Journal of Clinical Nutrition* 2003, **57**(9):1089-1096.
362. Waters E, de Silva Sanigorski A, Hall B, Brown T, Campbell K, Gao Y, Armstrong R, Prosser L, Summerbell C: **Interventions for preventing obesity in children (review)**. *Cochrane collaboration* 2011(12):1-212.
363. van Hees VT, Renström F, Wright A, Gradmark A, Catt M, Chen KY, Löf M, Bluck L, Pomeroy J, Wareham NJ: **Estimation of daily energy expenditure in pregnant and**

non-pregnant women using a wrist-worn tri-axial accelerometer. *PLoS One* 2011, **6**(7):e22922.
364. Greenland S, Drescher K: **Maximum likelihood estimation of the attributable fraction from logistic models**. *Biometrics* 1993:865-872.
365. Pearson N, Biddle SJ: **Sedentary behavior and dietary intake in children, adolescents, and adults: a systematic review**. *American Journal of Preventive Medicine* 2011, **41**(2):178-188.
366. Chaput JP, Klingenberg L, Astrup A, Sjödin A: **Modern sedentary activities promote overconsumption of food in our current obesogenic environment**. *Obesity reviews* 2011, **12**(5):e12-e20.
367. Maher CA, Mire E, Harrington DM, Staiano AE, Katzmarzyk PT: **The independent and combined associations of physical activity and sedentary behavior with obesity in adults: NHANES 2003-06**. *Obesity* 2013, **21**(12):E730-E737.
368. Popkin BM, Adair LS, Ng SW: **Global nutrition transition and the pandemic of obesity in developing countries**. *Nutrition Reviews* 2012, **70**(1):3-21.
369. Rückinger S, von Kries R, Toschke AM: **An illustration of and programs estimating attributable fractions in large scale surveys considering multiple risk factors**. *BMC medical research methodology* 2009, **9**(1):7.
370. Lake JK, Power C, Cole TJ: **Child to adult body mass index in the 1958 British birth cohort: associations with parental obesity**. *Arch Dis Child* 1997, **77**(5):376.
371. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH: **Predicting obesity in young adulthood from childhood and parental obesity**. *N Engl J Med* 1997, **337**:869-873.
372. Gluckman P, Hanson M, Buklijas T: **A conceptual framework for the developmental origins of health and disease**. *J Dev Orig Health Dis* 2010, **1**(1):6-18.
373. Knai C, Lobstein T, Darmon N, Rutter H, McKee M: **Socioeconomic Patterning of Childhood Overweight Status in Europe**. *Int J Environ Res Public Health* 2012, **9**(4):1472-1489.
374. Hesketh K, Crawford D, Salmon J, Jackson M, Campbell K: **Associations between family circumstance and weight status of Australian children**. *Int J Pediatr Obes* 2007, **2**(2):86-96.
375. Júlíusson PB, Eide GE, Roelants M, Waaler PE, Hauspie R, Bjerknes R: **Overweight and obesity in Norwegian children: prevalence and socio-demographic risk factors**. *Acta Paediatrica* 2010, **99**(6):900-905.
376. Gibson LY, Byrne SM, Davis EA, Blair E, Jacoby P, Zubrick SR: **The role of family and maternal factors in childhood obesity**. *Medical Journal of Australia* 2007, **186**(11):591-595.
377. Lioret S, Touvier M, Dubuisson C, Dufour A, Calamassi-Tran G, Lafay L, Volatier JL, Maire B: **Trends in Child Overweight Rates and Energy Intake in France From 1999 to 2007: Relationships With Socioeconomic Status**. *Obesity* 2009, **17**(5):1092-1100.
378. Wardle J, Guthrie C, Sanderson S, Birch L, Plomin R: **Food and activity preferences in children of lean and obese parents**. *Int J Obes* 2001, **25**(7):971-977.
379. Grunert KG, Shepherd R, Traill WB, Wold B, Malherbe F: **Food choice, energy balance and its determinants: Views of human behaviour in economics and psychology**. *Trends Food Sci Technol* 2012, **In press**(0).
380. Sonestedt E, Roos C, Gullberg B, Ericson U, Wirfält E, Orho-Melander M: **Fat and carbohydrate intake modify the association between genetic variation in the FTO genotype and obesity**. *Am J Clin Nutr* 2009, **90**(5):1418.
381. Cecil JE, Tavendale R, Watt P, Hetherington MM, Palmer CNA: **An obesity-associated FTO gene variant and increased energy intake in children**. *N Engl J Med* 2008, **359**(24):2558-2566.

382. Bauer F, Elbers CC, Adan RAH, Loos RJF, Onland-Moret NC, Grobbee DE, van Vliet-Ostaptchouk JV, Wijmenga C, van der Schouw YT: **Obesity genes identified in genome-wide association studies are associated with adiposity measures and potentially with nutrient-specific food preference**. *Am J Clin Nutr* 2009, **90**(4):951.
383. Hesketh K, Carlin J, Wake M, Crawford D: **Predictors of body mass index change in Australian primary school children**. *Int J Pediatr Obes* 2009, **4**(1):45-53.
384. Lazzeri G, Pammolli A, Pilato V, Giacchi M: **Relationship between 8/9-yr-old school children BMI, parents' BMI and educational level: a cross sectional survey**. *Nutrition Journal* 2011, **10**(1):76.
385. Hannon PA, Bowen DJ, Moinpour CM, McLerran DF: **Correlations in perceived food use between the family food preparer and their spouses and children**. *Appetite* 2003, **40**(1):77-83.
386. Whitaker RC, Dietz WH: **Role of the prenatal environment in the development of obesity**. *J Pediatr* 1998, **132**(5):768-776.
387. Lawlor DA, Smith GD, O'Callaghan M, Alati R, Mamun AA, Williams GM, Najman JM: **Epidemiologic Evidence for the Fetal Overnutrition Hypothesis: Findings from the Mater-University Study of Pregnancy and Its Outcomes**. *Am J Epidemiol* 2007, **165**(4):418-424.
388. Wake M, Baur LA, Gerner B, Gibbons K, Gold L, Gunn J, Levickis P, McCallum Z, Naughton G, Sanci L: **Outcomes and costs of primary care surveillance and intervention for overweight or obese children: the LEAP 2 randomised controlled trial**. *BMJ: British Medical Journal* 2009, **339**.
389. Hollinghurst S, Hunt L, Banks J, Sharp D, Shield J: **Cost and effectiveness of treatment options for childhood obesity**. *Pediatric Obesity* 2013.
390. MacDonald JM, Nelson Jr PE: **Do the poor still pay more? Food price variations in large metropolitan areas**. *Journal of Urban Economics* 1991, **30**(3):344-359.
391. Kaufman PR, MacDonald JM, Lutz SM, Smallwood DM: **Do the poor pay more for food? Item selection and price differences affect low-income household food costs**. United States Department of Agriculture, Economic Research Service; 1997.
392. Rose D, Richards R: **Food store access and household fruit and vegetable use among participants in the US Food Stamp Program**. *Public health nutrition* 2004, **7**(08):1081-1088.
393. Mooney C: **Cost and availability of healthy food choices in a London health district**. *Journal of Human Nutrition and Dietetics* 1990, **3**(2):111-120.
394. Cummins S, Macintyre S: **The location of food stores in urban areas: a case study in Glasgow**. *British Food Journal* 1999, **101**(7):545-553.
395. Cummins S, Macintyre S: **A systematic study of an urban foodscape: the price and availability of food in Greater Glasgow**. *Urban Studies* 2002, **39**(11):2115-2130.
396. Skidmore P, Welch A, van Sluijs E, Jones A, Harvey I, Harrison F, Griffin S, Cassidy A: **Impact of neighbourhood food environment on food consumption in children aged 9-10 years in the UK SPEEDY (Sport, Physical Activity and Eating behaviour: Environmental Determinants in Young people) study**. *Public health nutrition* 2010, **13**(7):1022-1030.
397. Jennings A, Welch A, Jones AP, Harrison F, Bentham G, Van Sluijs EM, Griffin SJ, Cassidy A: **Local food outlets, weight status, and dietary intake: associations in children aged 9–10 years**. *American Journal of Preventive Medicine* 2011, **40**(4):405-410.
398. Casey R, Chaix B, Weber C, Schweitzer B, Charreire H, Salze P, Badariotti D, Banos A, Oppert J, Simon C: **Spatial accessibility to physical activity facilities and to food outlets and overweight in French youth**. *International Journal of Obesity* 2012, **36**(7):914-919.

399. Cullinan J: **A spatial microsimulation approach to estimating the total number and economic value of site visits in travel cost modelling**. *Environmental and Resource Economics* 2011, **50**(1):27-47.
400. Sallis JF, Taylor WC, Dowda M, Freedson PS, Pate RR: **Correlates of vigorous physical activity for children in grades 1 through 12: Comparing parent-reported and objectively measured physical activity**. *Pediatric Exercise Science* 2002, **14**(1):30.
401. **Electoral Division Boundaries** [http://census.cso.ie/censusasp/saps/boundaries/eds_bound.htm]
402. Williams J, Scarborough P, Matthews A, Cowburn G, Foster C, Roberts N, Rayner M: **A systematic review of the influence of the retail food environment around schools on obesity-related outcomes**. *Obesity reviews* 2014.
403. Day PL, Pearce J: **Obesity-promoting food environments and the spatial clustering of food outlets around schools**. *American Journal of Preventive Medicine* 2011, **40**(2):113-121.
404. Simon PA, Kwan D, Angelescu A, Shih M, Fielding JE: **Proximity of fast food restaurants to schools: Do neighborhood income and type of school matter?** *Preventive medicine* 2008, **47**(3):284-288.
405. Ellaway A, Macdonald L, Lamb K, Thornton L, Day P, Pearce J: **Do obesity-promoting food environments cluster around socially disadvantaged schools in Glasgow, Scotland?** *Health & place* 2012, **18**(6):1335-1340.
406. Lucan SC: **Concerning Limitations of Food-Environment Research: A Narrative Review and Commentary Framed around Obesity and Diet-Related Diseases in Youth**. *Journal of the Academy of Nutrition and Dietetics* 2014.
407. Charreire H, Casey R, Salze P, Simon C, Chaix B, Banos A, Badariotti D, Weber C, Oppert J-M: **Measuring the food environment using geographical information systems: a methodological review**. *Public health nutrition* 2010, **13**(11):1773-1785.
408. **Healthy Ireland: A framework for improved health and wellbeing** [http://www.dohc.ie/issues/healthy_ireland/]
409. Fisher JO, Johnson RK, Lindquist C, Birch LL, Goran MI: **Influence of body composition on the accuracy of reported energy intake in children**. *Obesity Research* 2000, **8**(8):597-603.
410. Livingstone M, Robson P, Wallace J: **Issues in dietary intake assessment of children and adolescents**. *British Journal of Nutrition* 2004, **92**:213-222.
411. **Let's take on Childhood Obesity** [https://www.safefood.eu/Childhood-Obesity/Welcome.aspx]
412. Szklo M, Nieto FJ: *Epidemiology: beyond the basics*: Jones & Bartlett Publishers; 2014.
413. Olson S: *The Current State of Obesity Solutions in the United States:: Workshop Summary*: National Academies Press; 2014.
414. Briggs AD, Mytton OT, Madden D, O'Shea D, Rayner M, Scarborough P: **The potential impact on obesity of a 10% tax on sugar-sweetened beverages in Ireland, an effect assessment modelling study**. *BMC Public Health* 2013, **13**(1):860.