# An Investigation into Children's Out-of-School Physical Activity

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**Abstract**

This thesis used a multi-methods approach to explore children's out-of-school physical activity (PA). Study 1 found that children living in the most deprived neighbourhoods represent an important target group for future PA and health interventions. Further, the study also revealed that self-reported PA was positively associated with independent mobility. Study 2 confirmed that the weekend was a period of low moderate-to-vigorous PA (MVPA), and revealed that raw PA levels derived from the wrist-worn GENEActiv are not comparable with hip-worn ActiGraph. Agreement between the devices differed according to PA intensity and time of day, with the greatest difference occurring in light PA (LPA) during school hours. Using children's recounted perceptions and experiences of out-of-school PA, study 3 demonstrated how an inclusive, interactive and child-centred methodology (i.e., write, draw show and tell; WDST) may be advantageous when compared to traditional singular qualitative methods. In study 4 parental safety concerns were reported to be the most consistent barrier to children's out-of-school PA. The family case studies demonstrated how family perceptions and constraints can influence children's out-of-school PA levels and activity mode (i.e., active school travel, outdoor play and organised sport). Such constraints include factors such as, school proximity, neighbourhood perceptions and family context. Study 5 revealed substantial intra-individual variability in children's weekend MVPA. PA diary data revealed that children's weekend PA was mostly unstructured in nature and undertaken with friends, whereas a greater proportion of parents' weekend PA was undertaken alone in structured settings. Family case studies demonstrated that in the selected cases MVPA levels and variability across weekends were contingent on mode of PA participation. This thesis contributes evidence to inform future out-of-school PA interventions. The research has demonstrated that children's out-of-school PA is influenced by a complex interaction of individual, social and environmental factors. Specific highlights include the family and neighbourhood environment. The weekend is associated with low PA and as such represents an important time period to promote PA in children. Future weekend PA interventions should target specific modes of activity, as the facilitators and barriers to these activities vary considerably. Moreover, in future, research and practice should focus on ways in which to modify neighbourhood attributes to support children's out-of-school active living.

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**Table of contents**

**List of tables**

**List of figures**

**List of boxes**

## Abbreviations

| Abbreviation | Definition |
|---|---|
| AGhip | Hip-worn ActiGraph GT3X+ |
| ANOVA | Analysis of variance |
| ANCOVA | Analysis of covariance |
| β | Beta coefficient |
| B | Boy |
| BMI | Body mass index (kg/m²) |
| Cl | Confidence interval |
| DO | Direct observation |
| EE | Energy expenditure |
| ENMO | Euclidean norm minus one |
| F | Female |
| G | Girl |
| GAwrist | Wrist-worn GENEActiv |
| HR | Heart rate |
| ICC | Intra-class correlation |
| IMD | Indices of multiple deprivation |
| IPAQ | International Physical Activity Questionnaire |
| LPA | Light intensity physical activity |
| M | Male |
| METs | Metabolic equivalent of tasks |
| MVPA | Moderate-to-vigorous intensity physical activity |
| *n* | Sample size |
| NHANES | National Health and Nutrition Examination Survey |
| NICE | National Institute for Clinical Excellence |

| | |
|---|---|
| OR | Odds ratio |
| PA | Physical activity |
| PAQ-C | Physical Activity Questionnaire for Children |
| SD | Standard deviation |
| SE | Standard error |
| SES | Socioeconomic status |
| SVM | Signal vector magnitude |
| UK | United Kingdom |
| VPA | Vigorous intensity physical activity |
| WDST | Write, draw, show and tell |
| WHO | World Health Organization |
| YPAPM | Youth Physical Activity Promotion Model |

# Chapter 1

# Introduction

# 1. Introduction

## 1.1 The research problem

For the purpose of this thesis, physical activity (PA) is defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure' (Caspersen et al. 1985:126). Children engage in a broad range of structured and unstructured physical activities (Payne, Townsend & Foster, 2013). These activities vary in intensity, incorporate a full range of body movements and are intermittent in nature (Baquet et al. 2007; Hay, 2013).

PA improves children's physical and mental health (Biddle & Asare, 2011; Janssen & LeBlanc, 2010; Poitras et al. 2016). In the UK and other developed countries, children are recommended to accumulate at least 60 minutes of MVPA daily to benefit health (Chief Medical Officers, 2011; World Health Organization, 2010). However, globally, PA levels among children are low (Hallal et al. 2012; Tremblay et al. 2014). This is especially so for UK children. The most recent UK PA surveillance data found that 79% of boys and 84% of girls aged 2–15 years fail to achieve the recommended levels of PA to benefit their health (The Health and Social Care Information Centre, 2013). Childhood is an important developmental stage during which health and lifestyle behaviours including PA are established (Marmot, 2010; Telama, 2009). Gaining insight into modifiable factors that influence children's PA may help inform more effective intervention strategies to promote PA during childhood. These intervention strategies may help confront the public health challenges associated with childhood inactivity.

There are various settings within which to promote child PA. These include settings such as the school, sports clubs, neighbourhood and home environment. To date, PA promotional strategies have often been school-based, promoting PA throughout the school day. Many of these have been minimally effective (Dobbins et al. 2013; Metcalf, Henley & Wilkin, 2012; Russ et al. 2015). The time children spend out-of-school presents an opportune period within which to promote PA. Firstly, children's PA levels are typically at their lowest out-of-school (Brooke et al. 2014; Fairclough et al. 2015). Secondly, out-of-school, children spend a considerable amount of time with their parents. Therefore, parents can serve as catalysts to increase children's out-of-school PA. Parents are among the strongest influences on children's PA (Mitchell et al. 2012; Stanley, Ridley & Dollman, 2012; Sterdt, Liersch & Walter, 2013), serving as PA 'gate keepers', role models, and sources of support (Beets, Cardinal & Alderman, 2010; Crawford et al. 2010; O'Connor & Brown, 2013).

Neighbourhood built environments are recognised as key determinants of children's PA (Christian et al. 2015; Ding et al. 2011). The influence of the built environment varies according to PA mode (McGrath, Hopkins & Hinckson, 2015; Stone et al. 2012). Built environmental characteristics such as street connectivity, cul-de-sacs, bicycle lanes and parks support children's unstructured PA (e.g., active travel, outdoor play; Laxer & Janssen, 2013; Mecredy Pickett & Janssen, 2011; Nasar, Holloman & Abdulkarim, 2015), whereas access to recreational facilities can support children's structured PA (e.g., sport, club participation; Eime et al. 2015; Golle et al. 2014; Telford et al. 2016**)**. Neighbourhood environments that are conducive to children's outdoor play and active travel (e.g., presence of garden/backyard, walkable neighbourhoods) are associated with higher levels of child PA (Collins et al. 2012; Marino et al. 2012; McCrorie, Fenton & Ellaway, 2014). However, not all such environments are conducive to children's PA (e.g., parks, playgrounds, and gardens/yards) and vary by neighbourhood socioeconomic status (SES; Bürgi et al. 2016; Sallis et al. 2012).

The neighbourhood social environment can also support children's PA, by being safer, cleaner and having less road traffic (Franzini et al. 2009; Timperio, Reid & Veitch, 2015). These factors influence the extent to which modes of PA, such as outdoor play and active travel, can be engaged in by children independent of adult supervision (i.e., independent mobility; Carver, Timperio, Crawford, 2012; Salmon et al. 2013). For example, children's outdoor play, is consistently associated with higher levels of PA (McMinn et al. 2013; Nilsson et al. 2009b), yet often restricted by parents in response to neighbourhood safety concerns (e.g., road safety and 'stranger danger') (Carver, Timperio & Crawford, 2008; Jago et al. 2009b; Lee et al. 2015). Studies have shown that children with greater independent mobility engage in greater PA (Oliver et al.

2016; Schoeppe et al. 2014). Therefore, from a public health perspective, strategies to promote children's independent mobility and time outdoors are important. As the majority of neighbourhood studies focus on journeys to school (Carver et al. 2014; Helbich et al. 2016; Panter, Jones & van Sluijs, 2008), there is limited evidence on built environmental factors specifically influencing children's out-of-school PA and health. Moreover, research in this area has been predominantly quantitative in nature (Kurka et al. 2015; Janssen, Ferrao & King, 2016; Oliver et al. 2015; 2016), and offers somewhat limited exploration of the factors that influence parents' decision making towards children's out-of-school PA and independent mobility.

The central aim of this thesis is to explore and understand underlying factors that direct children's out-of-school PA. Children's out-of-school PA is a complex behaviour influenced by broad ranging factors operating at multiple levels (i.e., individual, social, environmental, and policy) (Sallis, Owen & Fisher, 2008). Therefore, this thesis adopts a socio-ecological approach to investigate the simultaneous influence of various objective and perceived environmental, social and individual factors on children's out-of-school PA. Whilst the focus is on children's out-of-school PA, the thesis acknowledges parents as key gatekeepers to children's out-of-school PA, and recognises that various factors drive parents' decision making which may influence children's out-of-school PA. In doing so, it is essential that the perceptions of parents as well as children are explored, in order to better understand children's out-of-school PA. In addition, the thesis aimed to provide a methodological contribution to the literature by extending beyond existing methodologies that objectively measure children's PA as well as those that elicit children's unique perspectives and lived experiences.

### 1.2 Organisation of the thesis

Understanding the determinants of children's out-of-school PA is a fundamental concern for health related research and practice. Sallis and Owen (1999) propose an organising framework termed the behavioural epidemiology framework (Figure 1.1). This framework identifies six key phases of research, as they may be applied to PA and health. Research on children's PA covers a broad range of topics, including epidemiological studies to identify the dose response relationship between PA and health, developing methods for accurate monitoring of PA, and examining factors influencing PA behaviour to inform intervention research and public health policy and practice.

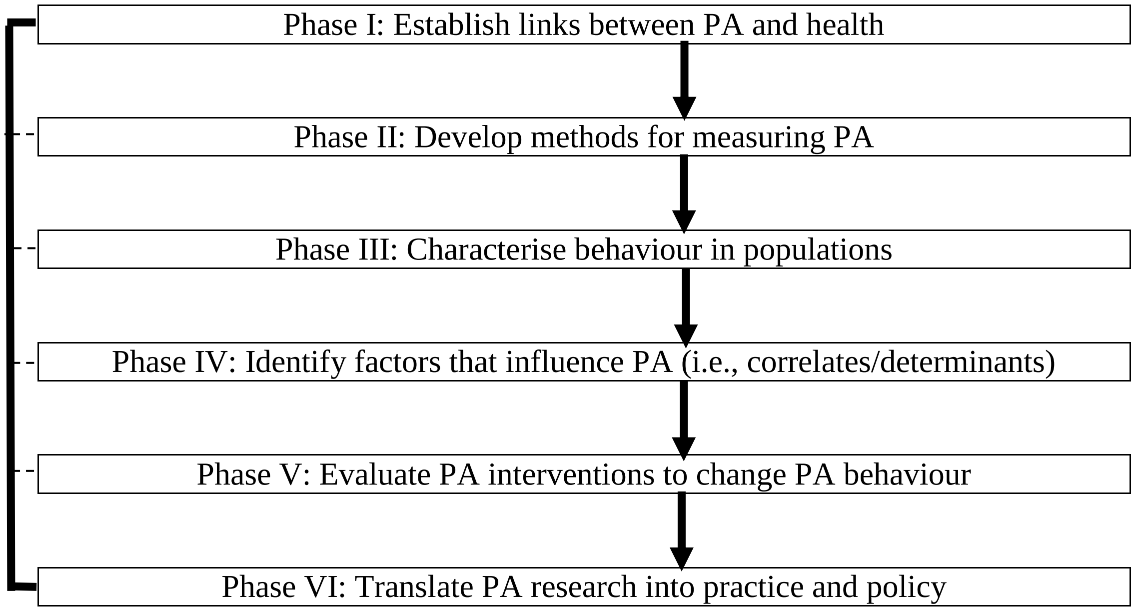



Figure 1.1 Behavioural epidemiological framework (Sallis & Owen, 1999)

The scope of this thesis centres on phases II, III and IV of the behavioural epidemiological framework. There is extensive research detailing PA prevalence rates in children (Cooper et al. 2015; Griffiths et al. 2013; Guinhouya, Samouda & de Beaufort, 2013) and characteristics associated with children’s general PA (Biddle et al. 2011a; Sterdt, Liersch & Walter, 2014). However, research detailing children’s context specific PA i.e., out-of-school PA and family-based PA is presently limited. In-depth contextual understanding of out-of-school PA characteristics and factors influencing children’s PA during the out-of-school period will better inform out-of-school PA intervention design and ensure that intervention content is appropriate and relevant to the target population and context specific settings. This thesis provides original research relating to the measurement of children’s PA (Phase II) and important modifiable correlates of children’s out-of-school PA (Phase IV). Although none of the studies presented in the thesis examine the relationship between PA and health (Phase I), or evaluate PA interventions (Phase V) the current evidence pertaining to these will be comprehensively presented within the literature review section of the thesis to present a rationale for the studies that follow.

Chapter 1 introduces the research problem. Chapter 2 builds on the introduction and provides a comprehensive review of the literature. The key topics discussed are measurement and prevalence of PA in children, consistent child PA correlates, and PA interventions targeting children. Chapter 3 describes the general methods that are common to all studies in the thesis. Where additional methods and procedures specific to studies were used these are described within the relevant chapters. Chapter 4 (Study 1) examines differences in health-related, home and neighbourhood environmental variables between children living in areas of high-deprivation and medium-to-high deprivation, and describes associations between perceived home and neighbourhood environments and health-related variables. Chapter 5 (Study 2) presents a quantitative study that investigates differences in wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data throughout the segmented week. Chapter 6, (Study 3) presents a qualitative study that used a novel combination of qualitative techniques to explore children's current views, experiences and perceptions of out-of-school PA. This study introduces a new dual-method (write, draw, show and tell; WDST) which represents an evolution of the write and draw and focus group method. A conceptual framework and practical checklist for its future application is presented. Parents' PA knowledge and perceptions of children's out-of-school PA are explored in Chapter 7 (Study 4). The final study, reported in Chapter 8, explores the variability and characteristics of weekend PA among families. Chapter 9 synthesises the results from each of the five studies, discusses the key findings and details the strengths and limitations of the thesis. Chapter 10 provides recommendations for future research and practice.

# Chapter 2

# Literature review

## Literature review

Following the structure of the behavioural epidemiological framework, the literature review chapter will briefly highlight the health-related benefits of PA for children, review the current literature on measurement approaches, present trends and consistent child PA correlates, and finally, evaluate previous intervention approaches to identify directions for future research. Evidence surrounding the importance of parents and the home environment as key correlates of children's PA will be discussed in detail to set the context for this thesis. Each research area will be reviewed separately and evidence from previous cross-sectional, longitudinal and experimental research will be used to discuss associations between variables and present a rationale for each study. Phase VI of the behavioural epidemiology framework is beyond the scope of this thesis but the concluding section of this chapter sets out where the research presented in this thesis builds upon existing evidence.

### 2.1. I: Establish links between physical activity and health

PA is associated with broad ranging health benefits for children (Janssen & LeBlanc, 2010; O'Donovan et al. 2010; Strong et al. 2005). The conclusion that PA is beneficial for children's health is based upon evidence from various observational (Boddy et al. 2014; Ekelund et al. 2012; Gobbi et al. 2012) and experimental studies (Kelloua et al. 2014; Maggio et al. 2012; Regaieg et al. 2013) in which higher levels of PA has been linked with more favourable health outcomes. The systematic review by Janssen and Leblanc (2010) reported a positive association between PA and various child health outcomes, and found a dose response relationship among observation studies indicating that the more PA children participate in the greater the observed health benefit.

There is growing consensus that vigorous intensity activities may provide additional health benefits for children compared with low to moderate intensity activities. Vigorous PA (VPA) has been linked with lower child adiposity (Chaput et al. 2012), and improved cardiometabolic health compared with PA performed at lower intensities (Carson et al. 2014; Farah et al. 2013; Füssenich et al. 2016; Hay et al.

2012). There is also some evidence to suggest that the negative impact of sedentary time can be alleviated by engaging in VPA (Moore et al. 2013).

Even small amounts of PA can have significant health benefits for children, particularly overweight and low active children (Janssen & Leblanc, 2010; Kelley, Kelley & Pate, 2014). Compared to VPA, the extent to which LPA contributes to children's health is far less understood. Although an inverse association has been reported between LPA and fat mass (Kwon et al. 2011) and diastolic blood pressure (Carson et al. 2013), other studies have found that only VPA was associated with improvements in waist circumference, body fat percentage, body mass index z score, systolic blood pressure and cardiorespiratory fitness (Aggio et al. 2015; Denton et al. 2013; Hay et al. 2012).

There are three key reasons for promoting regular PA during childhood: (I) to promote physical health and well-being during childhood, (II) to modify disease risk factors in order to minimise future degenerative diseases, and (III) to develop active lifestyles at an early stage of life in order that it might be continued into adult life (Boreham & Riddoch, 2001). The evidence supporting these three rationales will be presented briefly in the opening section of the literature review.

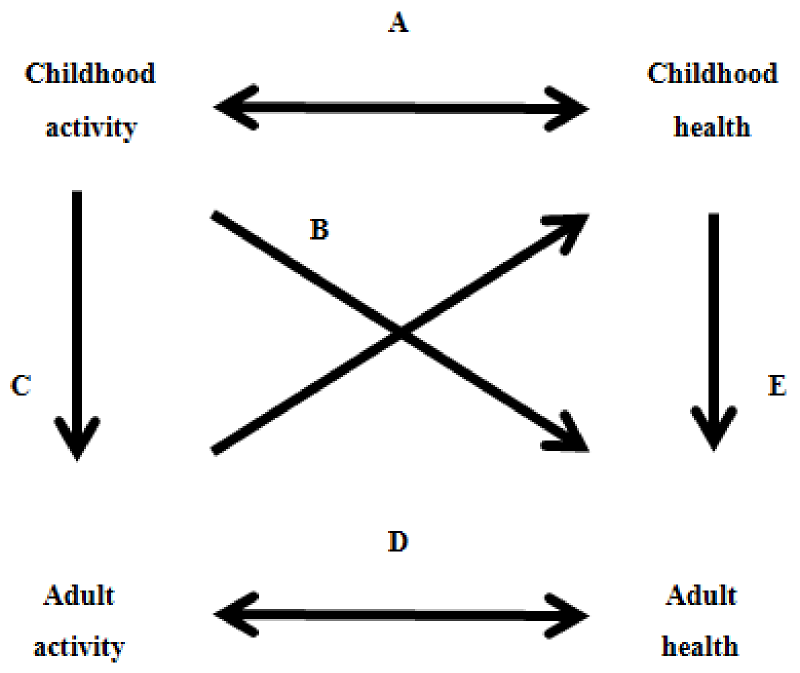



Figure 2.1 Hypothetical relationships between PA and health in children and adults.

### 2.2.1 Child physical activity and current health status

The first pathway represents the benefits of PA on childhood disease risk factors and the effect of PA for treating diseases and maintaining good health in childhood. There is strong evidence linking PA with improved weight status (Guinhouya, 2012; Hills, Andersen & Byrne, 2011; Katzmarzyk et al. 2015), CRF (Boddy et al. 2014; Kristensen et al. 2010; Serra-Paya et al. 2015), cognitive development (Carson et al. 2016; Fedewa & Ahn, 2011), academic attainment (Booth et al. 2014; Buscemi et al. 2014; Hillman, Erickson & Kramer, 2008; Howie & Pate, 2012; Singh et al. 2012), self-esteem, (Ahn & Fedewa, 2011; Ekeland, Heian & Hagen, 2005; Liu, Wu & Ming, 2015; Wood et al. 2013), and fundamental movement proficiency (Lubans et al. 2010). PA is also positively associated with improved musculoskeletal health (Janz et al. 2015; Maggio et al. 2012; Meyer et al. 2011), and a range of cardiometabolic risk factors (Boddy et al. 2014; Chaput et al. 2013; Ekelund et al. 2012; Füssenich et al. 2016; Gobbi et al. 2012; Vaisto et al. 2014). However, the evidence base linking PA with child health is largely derived from cross-sectional studies using subjective measures of PA (Biddle & Asare, 2011; Janssen & Leblanc, 2010). Further experimental research employing objective measures of PA and longitudinal study designs is needed.

### 2.2.2 Child physical activity and future health status

The second pathway represents the direct impact of childhood PA on adult health and disease. The evidence supporting this pathway is limited in comparison to the first pathway due to the challenges associated with long-term follow up of children into adulthood (Reiner et al. 2013). There is though, some evidence to support the positive link between childhood PA and adult health, particularly for weight status (Herman et al. 2009; Singh et al. 2008; Trinh et al. 2013), cardiometabolic (Bugge et al. 2013; Knowles et al. 2013; Rangul et al. 2012), musculoskeletal (Baxter-Jones et al. 2008; Bielemann et al. 2014) and psychological health (Hallal et al. 2015; Rangul et al. 2012).

### 2.2.3 Child physical activity as a habit

'Tracking' relates to the stability or persistence of a behaviour such as PA, over time (Boreham & Riddoch, 2001). In the context of PA, if a child maintained a consistent level of PA from childhood to adulthood, PA would be considered to track well (Van Oort et al. 2013). The notion is that active children are more likely to lead active lifestyles throughout adulthood (i.e., during adulthood) (Jones et al. 2013). While PA appears to track strongly between childhood and adolescence (Basterfield et al. 2015; Janz, Dawson & Mahoney, 2000) and into early adulthood (Herman et al. 2009); tracking from childhood through to adulthood is less consistent (Telama, 2009). Research suggests that tracking coefficients may be gender and time specific. For example, a large-scale study using pooled accelerometry data found higher PA tracking on weekdays compared to weekend days, and high tracking of inactivity among inactive girls but low tracking of PA among active girls (Kwon & Janz, 2012). Tracking coefficients may also be dependent on the type of PA engaged in as well as the duration and consistency of participation during childhood (Belanger et al. 2015). For example, Smith and colleagues (2015) found that UK children who participated in sport at age 10 were significantly more likely to participate in sport/PA at age 42, whereas no association was found between active outdoor play and adult sport/PA participation.

Several studies have investigated the long-term tracking of PA from childhood to adulthood. A Finnish study reported relatively strong tracking of recreational outdoor activity from age 13-23 years, and found that engagement in various types of PA provided greater opportunity for establishing lifelong involvement in PA (Kjonniksen, Torsheim & Wold, 2008). Similarly, regular participation in sports during adolescence has been linked with higher levels of PA in adulthood (Tammelin et al. 2003). Telama et al. (2005) conducted a 21-Year Tracking Study that assessed PA levels from childhood through to adulthood. The study commenced in 1980, when participants were aged 3, 6, 9, 12, 15, and 18 years (total of 2309 subjects), and measurements were repeated in 1983, 1986, 1989, 1992, and 2001. PA was measured by self-report questionnaire that assessed aspects including frequency and intensity of leisure-time PA, participation in sport club training, participation in competitive sport events, and type of school travel. Data revealed that a high level of PA between 9 and 18 years, especially when continuous, significantly predicted a high level of adult PA. Moreover, a lifespan longitudinal cohort study that assessed PA at seven different time points (1922, 1936, 1940, 1950, 1960, 1972, and 1977) found PA to be stable from childhood through to middle and late adulthood (Friedman et al. 2008). Active children in this particular study typically led active lifestyles into and during late adulthood.

While some studies have found childhood PA to be a key predictor of adult PA, associations have generally been weak to modest (Boreham et al. 2004; Trudeau, Laurencelle & Shepard, 2004; Telama, 2009). Moreover, much of the available evidence is drawn from Scandinavian countries and may be unrepresentative of UK children. This area of research is hampered by the methodological challenges of assessing PA at different time points throughout the life course. PA is also a highly unstable behaviour and is widely affected by major life experiences such as the transition from primary to secondary school, and relocating to a new neighbourhood (Boreham & Riddoch, 2003). This naturally results in irregular activity patterns within individuals over extended periods of time (Marks et al. 2015). Further longitudinal studies are needed using objective measures to confirm the strength of the stability of PA from childhood to adulthood, and to examine specific factors that influence PA tracking (Jones et al. 2013).

## 2.3 II: Develop methods for measuring physical activity

Children's PA is a complex multifaceted behaviour that is challenging to assess accurately (Hay, 2013). Compared to adults, children's PA is more sporadic and intermittent and often accumulated in bursts of high intensity activity throughout the day rather that structured blocks of activity (Baquet et al. 2007; Welk, Corbin & Dale, 2000). Additionally, children's PA typically involves activities that encompass a full range of body movements, such as chasing games and climbing (Barron, 2013). An early phase of the behavioural epidemiology framework is to identify valid and reliable methods to assess PA (Sallis & Owen, 1999). Reliable and valid PA measures are essential for informing all phases of the behavioural epidemiology framework, including, establishing the dose response relationship between PA and child health, assessing whether children are meeting recommended levels of PA, investigating multi-level factors (i.e., biological, demographic, psycho-social and environmental) that influence activity levels, and to establish the efficacy of child PA interventions (Ridgers & Fairclough, 2011; Trost, 2007).

A broad range of PA measurement tools are available to assess children's PA, but none are able to assess all domains and dimensions of PA (Dollman et al. 2009). PA assessment tools are categorised as either subjective (i.e., questionnaires, diaries, logs, recalls) or objective measures (i.e., motion sensors: accelerometers and pedometers, heart rate monitoring, direct observation and doubly labelled water). Although subjective and objective measures can be used independently to assess child PA, using both measures in combination can provide a more accurate and detailed assessment of children's PA (Troiano et al. 2012). Various studies have used multiple measures to assess children's PA (Bringolf-Isler et al. 2012; Kavanaugh et al. 2015; Slootmaker et al. 2009). However, using multiple measures places additional burden on children, which may influence adherence to the monitoring protocol (i.e., compliance) (Dollman et al. 2009). The advantages and disadvantages of common PA measurement approaches used in free-living contexts are discussed below.

### 2.3.1 Self-report

Self-report questionnaires are the most widely used measure of child PA. The main reason for their popularity is that they are a cheap and relatively easy way of collecting PA data from many children in a short time (Loprinzi & Cardinal, 2011). Additionally, questionnaires impose little burden on children and provide information regarding the type of PA that has been performed such as sport, transportation or play, as well as the context within which the activity has been performed (i.e., family-based or school-based) (Rachele et al. 2012). This contextual information is particularly advantageous when exploring out-of-school PA or evaluating the efficacy of programmes targeting specific contexts (Dollman et al. 2009). However, questionnaires have several limitations. They are attributable to social desirability bias and often overestimate PA levels (Troiano et al. 2008). Moreover, they are dependent upon children understanding and interpreting questions correctly in order to report accurate PA estimates (Janz et al. 2008). Questionnaires that include questions on activity type rather than time spent in activity are considered more reliable than those that assess minutes spent in activity (Saint-Maurice et al. 2014a). In addition, recalling recent activity is considered easier and more reliable than recalls of longer periods for children of all ages (Biddle et al. 2011b).

Self-report questionnaires are known to overestimate PA compared to objective measures (Adamo et al. 2009). This overestimation is often due to children reporting the total duration of an activity session rather than the total time that they engaged in activity during the activity session (Hussey, Bell & Gormley, 2007). A further limitation of self-report measures is their inability to accurately classify PA intensity (Rachele et al. 2012). Accurate assessment of PA intensity is particularly important because high intensity PA may yield greater health benefits for children compared with activity performed at the low or moderate intensity level (Chaput et al. 2012; Farah et al. 2013). It is common for children's LPA and moderate PA to be underestimated by self-report, whereas hard and vigorous PA are consistently overestimated (Adamo et al. 2009).

Some studies have used parent report (i.e., proxy report) rather than child self-report to assess child PA (Burdette, Whitaker & Daniels, 2004; Vaughn, Hales & Ward, 2013). Data from parent-report often provides an unrepresentative account of children's activity levels. A key reason for this is that parents are not always in contact with their child throughout the whole day which limits their ability to account for all activities that children have taken part in (Galas & Florek, 2013; Sarker et al. 2015; Thorn et al. 2013). Computerised questionnaires have grown in popularity and have numerous advantages over paper-based formats (Saint-Maurice & Welk, 2014). Cost and time saving are their main advantages, but they also eliminate coding error and enable instant data entry, which provides immediate data scoring and interpretation of results (Warren et al. 2010).

Recently, researchers have demonstrated the potential utility of calibrating self-report measures against objective monitors to convert self-report scores to time spent in PA (Saint-Maurice et al. 2014a; Saint-Maurice & Welk, 2014; 2015). Saint-Maurice et al. (2014a) found that the calibration model enabled the Physical Activity Questionnaire (PAQ) to provide a group-level prediction of time spent in MVPA, and in turn classify youth meeting the PA guidelines. More recently, Saint-Maurice and Welk (2014) developed the web-based self-report Youth Activity Profile (YAP) tool. The YAP has been shown to accurately estimate activity levels in groups of youth when calibrated against objective monitors (Saint-Maurice & Welk, 2015). The YAP may therefore serve as a valid alternative tool to activity monitoring for estimating MVPA in groups of youth in the future.

### 2.3.2 Direct observation

Direct observation (DO) is an objective assessment technique that is most suited for use in small samples (McKenzie, 2002). This particular measurement approach is advantageous to studies investigating children's PA in specific settings such as playtime (Ridgers, Stratton & McKenzie, 2010) or leisure time (McKenzie et al. 2000; 2006). Observation studies can also provide information on factors that may influence children's PA such as the social or physical environment and can thus aid the interpretation of study findings (Warren et al. 2010). Moreover, due to its high internal validity, DO has been widely used as a criterion measure for validating other data collection tools such as pedometers and accelerometers (McKenzie & van der Mars, 2015). Though the approach is advantageous in that it can accurately describe what took place in the activity setting, providing rich quantitative and qualitative data, the cost and time intensive nature of the method, both to train researchers and collect data needs to be considered (Dale, Welk & Matthews, 2002; Dollman et al. 2009). Also, to ensure reliable data observer monitoring, observer retraining is required throughout the data collection process to reduce the potential of an observer's skills deteriorating over time (McKenzie, 2002). Additionally, it is also important to acknowledge the effect observer presence may have on children's activity behaviour, though this can be minimised by conducting repeat observations (Trost, 2007).

### 2.3.3 Heart rate

Heart rate (HR) monitors provide an objective measure of children's PA. Heart rate monitors use the electrical signal from the heart to measure each heartbeat. The electrical signal is detected by a chest strap and transmitted to a receiver positioned on the wrist. The receiver has a built in clock that measures the timing and patterns of change in heart rate (Janz, 2002). The use of HR data to assess PA is centred on the linear relationship between heart rate and oxygen uptake (Hussey, Bell & Gormley, 2007). The main strengths of using heart rate monitoring to assess children's PA include their objectivity, relatively low cost and unobtrusiveness, as well as their ability to record data over time providing a visual assessment of both the pattern and intensity of children's activity (Loprinzi & Cardinal, 2011; Rowlands & Eston, 2007). HR has generally been used in combination with other measures to estimate daily PA in children (Collins et al. 2015; De Bock et al. 2010; Duncan, Badland & Schofield, 2009; Eyre et al. 2015), but has also been used as a single measure of PA (Massin et al. 2005; Wilson et al. 2011).

Although the relationship between HR and instantaneous PA energy expenditure (EE) is almost linear during moderate to vigorous intensity PA, the relationship is much weaker during low-intensity levels causing imprecision (Armstrong & Welsman, 2006). Because most children spend a large proportion of their day in sedentary or

LPA, using heart rate monitors can introduce significant measurement error and provide invalid estimates of PA (Riddoch et al. 2007; Trost, 2007). Furthermore, there is a delay in heart rate response after movement, which may mask the intermittent activity patterns of children (Baquet et al. 2007). In addition, since HR response typically lags behind changes in movement, HR it is unlikely to provide an accurate representation of children's habitual PA levels. Moreover, heart rate is influenced by a range of other factors including age, body size, CRF, stress response and hydration, and is impractical to use in large-scale studies (Loprinzi & Cardinal, 2011).

### 2.3.4 Pedometers

Pedometers are traditionally worn at the waist. They are the simplest form of motion sensor providing estimates of the number of steps taken over a set time period (Berlin, Storti & Brach, 2006). The main advantages to using pedometers include their relative low cost and objectivity making them feasible tools for the assessment of children's ambulatory PA in large-scale studies (Craig et al. 2010; Duncan, Scott-Duncan & Schofield, 2008; Laurson et al. 2008). However, they have been viewed as relatively inaccurate measures of PA, particularly at low and high walking speeds (Berlin, Storti & Brach, 2006). Newer electronic versions can store daily step values for the previous 7 days, and record information about the time when the sensor was in motion, providing greater insight into children's PA behaviour (Beighle & Pangrazi, 2006).

Pedometers have several key limitations. Most importantly, pedometers only measure steps taken. Additionally, they are unable to provide detail on PA intensity, which prohibits discussion of study findings in relation to public health PA guidelines (Trost, 2007). Furthermore, output measures are not comparable between studies using different pedometer brands or across age groups due to differences in stride length (Corder et al. 2008). Moreover, pedometers are unsuitable for water activities, susceptible to tampering and data loss, and have been known to underestimate step frequency at slow walking speeds (Beets, Patton & Edwards, 2005). Their accuracy is also compromised when placed at different body locations and used in certain populations (i.e., older adults and those with gait impairments). Finally, they are insensitive to non-locomotive and upper body movements, which limits their use in studies investigating children’s free-living PA (Rowlands & Eston, 2007; Warren et al. 2010).

Notwithstanding these limitations, evidence from a recent review study revealed that newer generation pedometers provide a valid and reliable objective measure of ambulatory activity in children aged over 5 years (Clemes & Biddle, 2013). The relatively simple nature of pedometer output (i.e., steps per day) and the limited number of data reduction techniques required to analyse the data make the devices suitable for comparing walking levels between populations and are particularly useful for screening purposes (Corder et al. 2008). Moreover, pedometers provide immediate feedback to the user on the number of steps taken, and therefore have the potential to serve as a motivational tool to encourage children to participate in more PA (Lubans, Morgan & Tudor-Locke, 2009).

### 2.3.5 Consumer devices

‘Fitness tracker’ monitors from companies such as Fitbit®, Jawbone®, and Nike© have increased in popularity in recent years. These contemporary devices have various advanced capabilities, allowing users to monitor body accelerations, EE, and sleep in addition to steps taken (Ainsworth et al. 2015). Although the accuracy of such devices is not well established in children, a recent review study found that consumer-level activity monitors showed moderate to strong validity for the measurement of adult steps, sleep duration, total daily EE, and MVPA during free-living conditions (Ferguson et al. 2015). Lee, Kim and Welk (2014) examined the validity of EE estimates in adults using various consumer-based PA monitors under free-living conditions. The findings revealed that the consumer-based monitors provided similar validity as the established SenseWear Mini and Core monitor. Evenson et al. (2015) also found high validity and inter-device reliability for steps, EE, and sleep for Fitbit models in adults. However, recent research found that consumer-based PA monitors accuracy for tracking EE and steps is dependent on the type of activity being performed (Nelson et al. 2016). The consumer-based PA monitors provided accurate measures of steps during structured ambulatory activity but were not accurate for measuring household steps. Further research investigating activity patterns and compliance to device wear with such devices is warranted in children.

### 2.3.6 Accelerometers

Accelerometers are the most widely used objective measure of child PA (Cain et al. 2013), and are the principle measure of PA in this thesis. Accelerometers provide a direct assessment of PA frequency, intensity and duration, unlike self-report and proxy-report PA measures (Dollman et al. 2009). Accelerometers are not reliant upon accurate recall or influenced by cognitive ability or social desirability (Rowlands, 2007). A key advantage of accelerometers is their time sampling capabilities. This enables researchers to investigate the most active and inactive periods of the day (Fairclough et al. 2012; Fairclough, Butcher & Stratton, 2007) or week (Fairclough et al. 2015). This facilitates correlate studies to examine factors associated with PA during specific time periods and segments of the day such as playtime (Ridgers et al. 2013), after school (Pearce et al. 2014), or weekends (McMinn et al. 2013). Such a feature is also particularly advantageous when assessing the efficiency of health promotion interventions targeting specific periods of the day (Jago et al. 2014; Saint-Maurice et al. 2014b).

Accelerometers do however have some limitations, which need to be considered. Accelerometers are expensive, can be burdensome, and the data is time consuming to analyse. Further, they provide limited contextual information and their cost prohibits their use in large-scale population studies (Dollman et al. 2009; Machado-Rodrigues et al. 2011). Moreover, most accelerometers are not waterproof which limits their ability to assess water-based activities (i.e., swimming), and when worn incorrectly they provide a biased estimate of PA. Furthermore, accelerometers are known to underestimate the EE of cycling (Tarp, Andersen & Østergaard, 2015) and activities involving upper body movement (Chen & Bassett, 2005), and have misclassified non-ambulatory light-to-moderate intensity activities (e.g., playing catch) as sedentary time (Trost et al. 2011).

#### 2.3.6.1 Counts acceleration data

Following body movement, the accelerometer produces a signal, which is then reduced into a meaningful metric. For counts based data reduction acceleration signals are summed, recorded over a set time sampling period (epoch), and stored in the internal memory as an arbitrary value referred to as a 'count' (Freedson, Pober & Janz, 2005). More recent studies have used raw accelerations instead of counts (van Hees et al. 2013; Fairclough et al. 2016; Hildebrand et al. 2014; Rowlands et al. 2014. 2015). The raw acceleration approach will be discussed in more detail later in the chapter.

The most common PA outcome in child PA research is time spent in different PA intensities (i.e., sedentary, light, moderate or vigorous). ‘Cut-points’ are used to classify the data collected over an epoch into a specific PA intensity. These cut-points are established during calibration studies where children perform various types of field (e.g., skipping or running) or laboratory (e.g., treadmill) activities while simultaneously wearing an accelerometer and criterion measure of EE (e.g., indirect calorimetry) or being observed (Evenson et al. 2008; Mackintosh et al. 2012). Traditionlly, researchers used the developed regression equations to define the linear relationship between accelerometer counts and EE (Bassett, Rowlands & Trost, 2012). Accelerometer activity counts are then compared against metabolic equivalents (METs), and counts corresponding to defined values for EE are classified as ‘cut-points’ (Kim, Beets & Welk, 2012). These cut-points are used to calculate the amount of time spent in sedentary, light, moderate, and vigorous PA.

The increased use of accelerometers has led to significant variation in the methods used by researchers to collect, process and report accelerometer data, which reduces comparability between studies and hinders evidence synthesis (Atkin et al. 2012; Cain et al. 2013). There are four key factors that can affect the PA data including choice of epoch length, the classification of a valid day, the number of valid days required to be included within analysis and the assigned cut-point threshold to the data (Ojiambo et al. 2011). These four key issues are discussed in detail throughout the following section of the thesis.

#### 2.3.6.1.1 Epoch

An epoch represents the amount of time over which activity counts are summed and recorded (McClain et al. 2008). The epoch length assigned to the accelerometer to record measurement data plays a key role in the amount of time a child is deemed to have spent engaged in MVPA (Vale et al. 2009). Longer epochs underestimate time spent at the extremes of the PA intensity distribution (i.e., sedentary and vigorous) because high and low intensity activity is averaged over a given epoch (Edwardson & Gorely, 2010a; Rowlands et al. 2006). A study examining the duration of PA bouts among children found that 80% of moderate PA bouts, 93% of vigorous PA bouts, and 96% of very high intensity PA bouts were shorter than 10 seconds in duration (Baquet et al. 2007). Because children's activity patterns tend to be short and sporadic in nature, short epoch lengths are recommended (i.e., ≤5 seconds) (Edwardson & Gorely, 2010a). McClain et al. (2008) found that using a shorter epoch minimised individual measurement error in children's MVPA during intermittent PA periods. Moreover, Ojiambo et al. (2011) found that epoch length selection significantly influenced MVPA time with roughly 10 minutes more MVPA time being recorded when a 15 s epoch was used compared with a 60 s epoch.

#### 2.3.6.1.2 Intensity cut-point threshold

Cut-points are used to classify the data captured within an epoch into a specific intensity level. Presently, there is no consensus on the most appropriate cut-point values to classify specific intensities of activity in children resulting in a large variation between researchers (Fischer et al. 2012). Consequently, it is difficult to compare findings across studies using different cut-points. The cut-points used to define PA intensities has a significant effect on PA prevalence and the number of children achieving PA guidelines (Pedišić & Bauman, 2015). A systematic review by Ekelund and colleagues (2011) found that the number of sufficiently active youth ranged from between 1% to 100% depending on the intensity thresholds used to classify activity. Employing a high MVPA cut-point will underrepresent children's engagement in MVPA and will reduce the number of children meeting PA guidelines. Alternatively, low cut-point values will have a contrasting effect on MVPA levels. Similarly, the use of high sedentary cut-points will misclassify a child's time spent in LPA and overestimate their time spent sedentary (Mackintosh et al. 2012). Cut-point selection has been shown to significantly influence study outcomes in a wide range of studies (Ekelund et al. 2011; Guinhouya, Samouda & de Beaufort, 2013; Loprinzi & colleagues, 2012) evidencing the need for a standardised cut-point to facilitate study comparability.

Evenson et al.'s (2008; Table 2.1) counts-based cut-points are considered the most accurate when assessing all activity intensities in children (Trost et al. 2011). Trost and colleagues (2011) evaluated the classification accuracy of five sets of independently developed ActiGraph cut-points (i.e., Evenson et al. 2008; Freedson et al. 2005; Mattocks et al. 2007b; Puyau et al. 2002; Treuth et al. 2004) and found that Evenson et al.'s (2008) and Freedson et al.'s (2005) MVPA cut-points exhibited significantly better classification accuracy than all other included cut-points. However, only Evenson et al.'s (2008) cut-points provided acceptable classification accuracy for all four levels of PA intensity (sedentary, light, moderate and vigorous activity).

Table 2.1 Evenson 'count' intensity cut-point thresholds

| Intensity classification | Cut-point value |
|---|---|
| Sedentary | ≤100 |
| Light | >100 |
| Moderate | ≥2296 |
| Vigorous | ≥4012 |

#### 2.3.6.1.3 Accelerometer non-wear

Children are generally required to wear the accelerometer during waking hours for seven consecutive days. They are instructed to only remove the monitor during water-based activities and when sleeping as monitors are not waterproof and can be uncomfortable to wear when sleeping. However, it is common for children to remove accelerometers at other times during the data collection period (Belton et al. 2013; Tudor-Locke, Johnson & Katzmarzyk, 2011). Monitor non-wear results in an output measure of consecutive zero counts and this produces analytical problems for researchers, partly due to difficulties determining whether a string of consecutive zero counts is due to monitor removal or sedentary time (Evenson & Terry, 2009). The easiest approach would be to delete zero count values from the dataset. However, this approach leads to extensive data loss and provides an inaccurate reflection of participant inactivity (Howie & Straker, 2016; Evenson & Terry, 2009).

Several approaches have been used to address the issue of missing accelerometer data including making assumptions about sleep time and comparisons against a wear time diary (Kristensen et al. 2008; Meltzer & Westin, 2011; Ottevaere et al. 2011). Another approach is to apply a decision rule that allows for a specific number and pattern of consecutive zeros throughout the day, referred to as the 'allowable interruption period'. Most studies classify non-wear time as ≥20 minutes of consecutive zero counts (Cain et al. 2013), though this figure ranges from 10 minutes (Moller et al. 2009; Nilsson et al. 2009a; Riddoch et al. 2004, 2007) to 180 minutes (Van Coevering et al. 2005).

Different non-wear time definitions result in variances in total wear time and the number of non-wear periods, and can significantly affect study findings depending on the outcome of interest (Chinapaw et al. 2014; Crevier-Couture et al. 2014; Janssen et al. 2015). Tanha et al. (2013) found that while the use of different wear time thresholds had no effect on minutes in different PA intensities, there was almost a threefold difference in minutes of daily sedentary time (i.e., ranged from 159 to 438 minutes) between the lowest and highest used threshold (i.e., 10 and 60 minutes). Esliger et al. (2005) reported that 76% of children aged 8–13 years had zero string bouts greater than 10 minutes (mean 17.5 minutes) suggesting a 20 min zero string rule is the most appropriate to use in children. Similarly, Janssen and colleagues (2015) found that using the 20 min rule provided the most accurate estimates of sedentary time and changes in sedentary time in 9–12 year-olds. The definition used for non-wear does not affect estimates of MVPA, as MVPA only includes higher intensity activity (Tanha et al. 2013).

#### 2.3.6.1.4 Number of measurement days and hours

Under free-living conditions children's PA levels vary both within and between days, therefore, the assessment of activity over a single day is unlikely to accurately reflect a child's habitual PA level (Collings et al. 2014; Mattocks et al. 2007a). Moreover, PA levels among children vary by season (Cooper et al. 2010; Hjorth et al. 2013; Riddoch et al. 2007), although, seasonal variation is seldom investigated due to the challenges of repeated measures study designs. Comparing results between studies conducted during different seasons is likely to produce contradictory findings. In cross-sectional research, seasonal effects are unlikely to affect findings as long as activity levels are assessed during a similar period of time (i.e., term time) (Rowlands & Eston, 2007).

Various studies have examined the number of days required to provide a representative measure of children's habitual PA but there is limited consensus across studies (Basterfield et al. 2011; Hislop et al. 2014; Kang et al. 2014; Mattocks et al. 2008; Rich et al. 2013). The spearman Brown Prophecy formula has been used to calculate the number of monitoring days required to achieve a desired level of reliability, which according to Cohen (1960) is $r>0.80$. While increasing the number of monitoring days reduces intra-individual variation and thus overall variation, it also places additional burden on children and could influence protocol adherence. Researchers typically define a minimum acceptable number of valid days required to be included in analyses in order to ensure that the included data is valid, reliable and representative of a child's habitual PA. There is however, no consensus as to how much time a child needs to wear the monitor during assessment of habitual PA, though, the figure generally ranges between 3 and 10 days (Cain et al. 2013). Although, Rich et al. (2013) reported that at least two days lasting ≥ 10 hours/day resulted in a reliable estimate of PA among a large sample of UK primary school aged children.

Criteria used for defining the number of sufficient days of wear time directly affects sample size and PA estimate reliability (Corder et al. 2008). Because weekend and weekday activity levels tend to differ (Fairclough, Ridgers & Welk, 2012; Rowlands, Pilgrim & Eston, 2008) some studies require a valid weekend day for inclusion in analysis, although many do not (Cain et al. 2013). Fewer numbers of days will retain a greater number of participants for analysis, but will reduce the reliability and validity of the data (Ridgers & Fairclough, 2011). Mattocks and colleagues (2008) examined the number of days of monitoring required to achieve reliability coefficients of 0.7, 0.8, and 0.9. Three days of monitoring were needed to achieve a coefficient of 0.7, irrespective of the valid day definition used (i.e., 420 or 600 registered minutes per day), whereas five and eleven days were needed to achieve a reliability coefficient of 0.8 and 0.9, respectively. The sample size decreased from 5,601 to 4,760 children when criteria was increased from 3 to 5 valid days (600 registered min/day), respectively, and participant numbers decreased by a further 11 and 5% with the additional requirement of both weekday and weekend representation.

Partial non-compliance is when a monitor is removed during the day for either a specified or a non-specific reason (Ridgers & Fairclough, 2011). The number of monitoring hours required to be deemed a valid day generally ranges between 6-12 hours. Applying less stringent wear time criteria allows for a larger sample size but increases the potential of underestimating activity levels (Lima et al. 2014). Ten hours of monitoring wear has been recommended as an appropriate criterion for young populations (Corder et al. 2008; Penpraze et al. 2006) and is the most widely used definition of a valid day according to a recent review study (Cain et al. 2013). However, another common approach used to classify a valid day is the '70/80' rule. This approach is a sample-specific means of setting wear time criteria for a valid day (Catellier et al. 2005). The '70/80' rule classifies a valid day as 80% of a time period defined by 70% of the sample having data (Catellier et al. 2005).

#### 2.3.6.1.5 Accelerometer wear compliance

Low participant wear-time (i.e., compliance) is a consistent limitation of studies using accelerometry (Corder et al. 2008; Jago et al. 2013b; Penpraze et al. 2006; Robertson et al. 2011; Van Coevering et al. 2005). The issue tends to arise because children are generally not required to wear the accelerometer for a complete 24 hours, creating significant variation in wear time between participants. In a large scale UK study involving 2048 children, aged 8–10 years, only 817 (40%) and 1629 (80%) children wore the accelerometer for the requested (5 days of 8 h/day) and required times (3 days of 8 h/day), respectively (Wells et al. 2013). Adherence to the study protocol tends to decrease with days of wear and is lowest at weekends (Zhuang et al. 2013). When investigating children's out-of-school and family-based PA it may be advantageous to distribute monitors later in the week (i.e., Thursday or Friday) to increase the chances of high participant wear time on weekend days and retain a large proportion of participants in analyses.

Twenty-four-hour wear time protocols would eliminate the need for children to replace the monitor in the morning, and would limit delayed replacement before and after bedtime. Non-wear in this case would only arise when children engage in water-based activities. Recent studies have used a 24-hour wear time protocol (Gomes et al. 2013; Taylor et al. 2013; Tudor-Locke et al. 2015), and it is likely to become the standardised approach in future studies. Aside from increasing participant wear time compliance it also provides the opportunity to study the relationship between PA, sleep and other health related variables, which have very important public health policy implications (Laurson et al. 2015; Hjorth et al. 2012; 2014; McNeil et al. 2015).

Various strategies have been used by researchers to improve device wear including reminder phone calls, monetary incentives, and monitor re-wear to achieve the required wear time (Belton et al. 2013; Sirard & Slater, 2009; Trost, McIver & Pate, 2005). However, there is evidence to suggest that the location and the monitor itself has the greatest influence on participant compliance. This is partly due to the need for monitor removal when changing clothing and engaged in water-based and physical contact activities (Cain et al. 2013). Young people have expressed concerns about the discomfort of wearing the monitor as well as the appearance, embarrassment and unwanted attention from others when wearing the monitor (Audrey et al. 2012; Kirby et al. 2012). They have also suggested that accelerometers would be more appealing to wear if they could be worn as a watch, sweatband, or bracelet (Kirby et al. 2012).

#### 2.3.6.2 Wrist-worn accelerometers

Wrist-worn accelerometers have grown in popularity on the basis of improving device wear. They have been used in a range of recent studies investigating PA in children (Fairclough et al. 2016; Hibbing et al. 2016; Hildebrand et al. 2014; Rowlands et al. 2014; 2015; Schaefer, Nace & Browning, 2014). Various studies have found wrist-worn accelerometry to be a valid measure of children's PA at varying intensities (Phillips, Parfitt & Rowlands, 2011; Ekblom et al. 2012; Vanhelst et al. 2013). Wrist-worn accelerometers can remain worn when changing clothing and are generally comfortable to wear during daily free-living activities. It is envisaged that because of these aforementioned factors increased monitor wear will be observed during PA assessment. This is advantageous to researchers as it increases data reliability (Routen et al. 2012). Participants in the NHANES adult study wore accelerometers at the hip between 2003 and 2006 and participant monitor compliance ranged between 40%–70% depending on participant age (i.e., based on ≥6 days of data and 10 hours of wear time). PA was then assessed using wrist-worn accelerometers between 2011 and 2012 and monitor compliance increased to between 70% and 80% with median wear time calculated as 21–22 hours (i.e., based on ≥6 days of data) (Freedson & John, 2013). Recently, Fairclough et al. (2016) found that the wrist placement promoted superior accelerometer device wear compared to the hip, thus confirming the wrist as a feasible accelerometer placement location in children.

#### 2.3.6.3 Raw acceleration data

As outlined earlier in this section, accelerometer device output is a proprietary and arbitrary 'count' value. Consequently, count data cannot be directly compared across devices due to differences in how the raw data are collected, processed, filtered, and scaled (Welk, McClain & Ainsworth, 2012). It has been suggested that if accelerometer device manufacturers were to open up their proprietary data processing algorithms, or alternatively, equivalent filtering and scaling methods were used by all accelerometer-based manufacturers, there would be opportunity for standardisation (Troiano et al. 2014). Parallel to these suggestions, experts in the field have called for a move away from the use of arbitrary count-based outputs towards an approach that summarises accelerometer data in gravity units (*g*) to aid comparisons across studies using different devices (John & Freedson, 2012). A recent advancement in accelerometer-based PA assessment is the development of devices capable of capturing and storing raw, unfiltered acceleration signals. Compared to the count based approach, the raw approach permits greater [end-used/researcher] control over post-data collection procedures, and in theory, facilitates comparison of data between studies using different accelerometer devices. Devices with this capability include the GENEActiv (Activinsights, Cambs, UK) and ActiGraph (GT3X+ and GT9X models; Figure 2.2).


Figure 2.2 An ActiGraph GT3X+ accelerometer attached to on an elasticated waistband, wrist-worn ActiGraph GT9X and GENEActiv models.

#### 2.3.6.3.1 GGIR

Raw accelerations are expressed in *g* or *g*/s$^{-1}$ as the gravity subtracted sum of the Signal Vector Magnitudes (SVM). Subtracting 1 removes the gravitational component and focuses the SVM on dynamic rather than static accelerations. The GENEActiv software produces the 1 s sum of the SVM of each raw data point to give the sum of the SVM in *g* units per second which is similar to Actigraph’s ‘count’ per epoch. However, summing the SVM values may introduce an unwanted dependency on sampling frequency (e.g., 10 Hz vs 100 Hz) and limit comparison of results between studies that have used different sampling frequencies (Hildebrand et al. 2014). Recent studies have instead calculated the mean SVM per second to facilitate the comparison of results across studies (Hildebrand et al. 2014; Schaefer et al. 2014). The calculation of the mean magnitude of dynamic acceleration is referred to as the Euclidean norm minus one (ENMO).

GGIR is an open source package that facilitates the processing of raw accelerometer signals in R [http:/cran.r-project.org]. The signal processing screens for non-wear and abnormally high values, calibrates the raw data and reduces the data to a meaningful and usable epoch based on ENMO-derived SVM. The final stage calculates time spent in intensities of PA based on user-defined cut-point thresholds (Rowlands et al. 2016c). A key advantage of GGIR is its ability to process and analyse raw data from different accelerometer brands (i.e., GENEActiv and ActiGraph) ensuring standardisation of data treatment across monitors (Rowlands et al. 2016c). Autocalibration is an important step in the data processing process as the ENMO statistic is vulnerable to calibration error because of the assumption that gravity is measured as 1*g* (van Hees et al. 2014).

Negative SVM values are the result of downward accelerations or device calibration error, which is not related to body movement (Hildebrand et al. 2014). There are alternative approaches to dealing with negative SVM values. Early calibration studies (Esliger et al. 2011; Phillips, Parfitt & Rowlands, 2011) converted negative raw data values to their absolute values, whereas recent studies have replaced negative values with zeros (da Silva et al. 2014; Fairclough et al. 2016; Hildebrand et al. 2014; van Hees et al. 2013). The latter approach is based on the premise that taking the absolute of a negative value will only correct for negative accelerations in the lower acceleration range, and may introduce nonlinearity into the overall range in VM values (Hildebrand et al. 2014).

#### 2.3.6.3.2 Sampling frequency and epoch

The GENEActiv and ActiGraph (i.e., GT3X+, GT9X models) collect and store raw accelerations at frequencies between 10 and 100 Hz. Presently, there is no standardised frequency used in child PA research. This has led to a broad range of frequencies used across studies. Studies using GENEActiv and GENEA have chosen 60 Hz (Hildebrand et al. 2014), 75 Hz (Schaefer et al. 2014), 80 Hz (Phillips, Parfitt & Rowlands, 2013), 85.7 Hz (Da Silva et al. 2014; Rowlands et al. 2014; 2015) and 100 Hz (Fairclough et al. 2016). Conversely, studies using the ActiGraph GT3X+ have chosen 80 Hz (Rowlands et al. 2014; 2015) and 100 Hz (Fairclough et al. 2016). Research conducted by Zhang et al. (2012) found that activity classification accuracy was not compromised when the sampling rate was decreased from 80 to 10 Hz. This is an important finding as lower sampling frequencies reduce data load, increase battery life, and speed up data processing.

The GGIR software reduces the raw data into a meaningful and usable epoch based on ENMO-derived SVM. Although there is no consensus on epoch length across studies, most studies have reduced the SVM data over a 1 second (Fairclough et al. 2016; Hildebrand et al. 2014; Rowlands et al. 2014) or 5 second epoch (da Silva et al. 2014; Rowlands et al. 2016b; 2016c).

#### 2.3.6.3.3 Intensity cut-point threshold

Several studies have developed child specific raw acceleration intensity cut-point thresholds (Hildebrand et al. 2014; Phillips et al. 2011; Schaefer et al. 2014). Phillips et al. (2011) and Schaefer et al. (2014) conducted calibration studies to establish child PA intensity cut-points for the GENEA and GENEActiv, respectively. All intensity cut-point thresholds, aside from the sedentary cut-point threshold were similar between the two studies. The discrepancy in sedentary cut-point threshold values between the two studies is most likely due to the variation in sedentary activities used in each study. For example, Schaefer et al. (2014) included upper body activities (i.e., colouring and Lego®), whereas Phillips et al. (2011) used activities involving minimal upper body movement (i.e., lying, sitting and DVD watching). More recently, Hildebrand et al. (2014) developed regression equations for the prediction of intensity

(METs) for GENEActiv and ActiGraph GT3X placed on the wrist and hip, based on the ENMO metric (Table 2.2). The regression equations were then used to classify raw acceleration intensity cut-point thresholds for MPA (3 METs) and VPA (6 METs) for wrist and hip-worn GENEActiv and ActiGraph GT3X in children aged 7-11 years (Table 2.3).

Table 2.2 Hildebrand regression equations for the prediction of intensity (METs) for wrist and hip-worn GENEActiv and ActiGraph in children.

| Device | Placement | Equation |
|---|---|---|
| ActiGraph | Hip | VO2 = 0.0559 x *mg* + 10.03 |
| GENEActiv | Hip | VO2 = 0.0498 x *mg* + 10.39 |
| ActiGraph | Wrist | VO2 = 0.0356 x *mg* + 10.83 |
| GENEActiv | Wrist | VO2 = 0.0357 x *mg* + 11.16 |

$VO_2$ is expressed in millilitres per kilogram per minute (mL $O_2 \cdot kg^{-1} \cdot min^{-1}$)

Table 2.3 Hildebrand 'raw' MPA (3 METs) and VPA (6 METs) intensity cut-point thresholds for wrist and hip-worn GENEActiv and ActiGraph in children.

| Device | Placement | MPA intensity threshold (*mg*) | VPA intensity threshold (*mg*) |
|---|---|---|---|
| ActiGraph | Hip | 142.6 | 464.6 |
| GENEActiv | Hip | 152.8 | 514.3 |
| ActiGraph | Wrist | 201.4 | 707.0 |
| GENEActiv | Wrist | 191.6 | 695.8 |

#### 2.3.6.3.4 Wear time

There is limited consensus regarding wear time inclusion criteria for raw accelerometer data. Wear time inclusion criteria appear to be generic to any accelerometer and similar to count based studies. Studies that have requested children to wear the monitor day and night have used a 16-hour inclusion criteria (Rowlands et al. 2014) whereas 10 hours of wear has been used in studies where children wore the monitor during waking hours (Fairclough et al. 2016).

#### 2.3.6.3.5 Accelerometer non-wear

Most studies that have used raw data processing methods (da Silva et al. 2014; Fairclough et al. 2016; Rowlands et al. 2014) have employed the non-wear criterion developed by van Hees et al. (2013). This approach estimates non-wear based on the standard deviation and value range of each axis, calculated for 60-min windows with 15-min moving increments. The time window is classified as non-wear when the standard deviation value for at least two of the three axes is < 0.013 *g* or if the range of these standard deviation values is less than 0.05 *g* (Sabia et al. 2014; van Hees et al. 2013). Using this time window ensures that short periods of inactivity or even sleep are not confused with non-wear time (van Hees et al. 2013).

#### 2.3.6.3.6 Research studies

Aside from the challenge of PA data comparability between device brands, another is the comparability of PA data from devices placed on different body locations such as the wrist and hip. Several studies have examined the comparability of raw PA data derived from wrist-worn GENEActiv and hip-worn ActiGraph and found PA outcomes to be higher at the wrist compared to the hip (Fairclough et al. 2016; Rowlands et al. 2014, 2015; Tudor-Locke, Barreira & Schuna, 2015). Rowlands et al. (2016c) examined agreement between wrist-worn GENEActiv and wrist-worn ActiGraph derived ENMO in 34 adults. Agreement between the GENEActiv and ActiGraph was weakest at very low accelerations and strongest at mid to high accelerations. The study found that ENMO was 7% higher for the GENEActiv compared to the ActiGraph. Conversely, an earlier study that compared ENMO between hip-worn GENEActiv and hip-worn ActiGraph in 58 children reported differences of between 12% and 13% for the two brands (Rowlands et al. 2015). Recently, Fairclough et al. (2016) compared children’s whole-day MPA and VPA derived from the GAwrist and AGhip. The study found that mean GAwrist values for both intensities were significantly higher than those from the AGhip, particularly at higher intensities.

Previous studies in this area have been limited to the reporting of whole-day PA estimates (Fairclough et al. 2016; Rowlands et al. 2014), raw accelerations (Rowlands et al. 2015), or steps (Tudor-Locke, Barreira & Schuna, 2015). Therefore, little is known about the comparability of PA levels across time segments and low PA intensities. Given the increased use of GENEActiv and other wrist-worn accelerometers in child PA research (da Silva et al. 2014; Keane et al. 2014; Wake et al. 2014), further research is needed to explore the comparability of wrist-worn GENEActiv and hip-worn ActiGraph derived raw PA levels across varying intensities and time segments in order to facilitate more precise estimates of children's PA.

## 2.4 III: Characterise physical activity in populations

### 2.4.1 Physical activity levels in the UK and other countries

Descriptive PA epidemiology studies are important for the latter phases of the behavioural epidemiology framework and public health. These studies identify inactive groups and target groups for intervention (Sallis & Owen, 1999). Many governments around the world have PA guidelines in an attempt to promote regular PA participation across all ages. In the past, activity guidelines were generic and applied to both adults and young people, however, more recently, age specific guidelines have been developed specifically for young people. Health experts in the UK (Chief Medical Officers, 2011) recommend that all young people aged 5-18 years should achieve the following:

1. All children and young people should engage in MVPA for at least 60 minutes and up to several hours every day.

2. Vigorous intensity activities, including those that strengthen muscle and bone, should be incorporated at least three days a week.

3. All children and young people should minimise the amount of time spent being sedentary (sitting) for extended periods.

Comparable guidelines are also advocated by the World Health Organization (World Health Organization, 2010) and countries including Australia (Australian Government Department of Health, 2014), Canada (Tremblay et al. 2011), and America (US Department of Health and Human Services, 2008). PA level data is important to determine the number of active and inactive children, assess generational trends, and to identify intervention target groups demonstrating low levels of PA. Children are considered to be 'meeting the guidelines' or classified as 'sufficiently active' if they have participated in at least 60 minutes of MVPA every day. This figure is generally calculated based on accelerometer MVPA cut-point values of around 2000 counts per minute but thresholds vary considerably limiting comparisons to be made between studies (Guinhouya, Samouda & de Beaufort, 2013).

Despite the well-established health benefits of PA (Janssen & LeBlanc, 2010; Poitras et al. 2016; Strong et al. 2005), UK (The Health and Social Care Information Centre, 2013) and international (Tremblay et al. 2014) surveillance data suggests that very few children currently achieve the recommended levels of PA to benefit their health. Data from the most recent Health Survey for England (HSE) 2012 suggested that 79% of boys and 84% of girls aged 2–15 years are not meeting guideline recommended levels of PA (The Health and Social Care Information Centre, 2013). A more recent large-scale UK study that assessed 7-8-year-old children's PA using accelerometers found that 51% of 7-year-old children achieved the PA guideline recommendation (Griffiths et al. 2013). However, these findings were based on 2 days of PA data and should therefore be interpreted with caution.

Regardless of the measurement approach (i.e., subjective or objective) used to assess PA, there is strong evidence to suggest that few children in the UK (Griffiths et al. 2013; The Health and Social Care Information Centre, 2013; Ness et al. 2007; Riddoch et al. 2007), America (Dentro et al. 2014), Australia (Schranz et al. 2014), Canada (Gray et al. 2014), and New Zealand (Maddison et al. 2014) currently achieve the recommended levels of PA to benefit their health. However, PA prevalence figures differ considerably between countries due to the large variation in accelerometry analytical procedures used across studies (Ekelund, Tomkinson & Armstrong, 2011; Guinhouya, Samouda & de Beaufort, 2013).

### 2.4.2 Physical activity levels by gender

Various studies have found that boys are more active than girls (Colley et al. 2011; Crespo et al. 2013; Fisher et al. 2011; Konstabel et al. 2014; Riddoch et al. 2007; Telford et al. 2013). Purslow et al. (2008) found significant gender differences in objectively measured PA in a UK longitudinal study involving 176 boys and 169 girls aged 8–9 years. Boys engaged in more minutes of MVPA than girls did and a greater percentage of boys (72%) than girls (30%) met current PA guidelines of 60 minutes MVPA per day. Furthermore, gender was the most consistent predictor of MPA and VPA on weekdays and weekend days in UK children aged 10 to 11 years (Fairclough, Ridges & Welk, 2012). PA gender differences have been reported in studies assessing PA using questionnaires and accelerometry (Hilland et al. 2011).

Accelerometer data from the 2008 HSE showed a decline in English children's PA levels with advanced age. Fifty-one percent of boys aged 4 to 10 year achieved the government guideline PA recommendations compared to 7% of boys aged 11 to 15. A similar pattern was observed among girls with 34% of girls aged 4 to 10 years achieving the recommended target compared to none of the girls aged 11 to 15 years (The Health and Social Care Information Centre, 2009). The HSE (2012) also found that the greatest decline in activity levels between 2008 and 2012 was in the 13-15 age group range for both boys and girls.

### 2.4.3 Physical activity levels by age

Various studies have reported a large decline in children's PA levels during the transition from childhood to adolescence (Basterfield et al. 2015; Dumith et al. 2011a; Metcalf et al. 2015; Sherar et al. 2007; Wickel & Belton, 2016). A recent UK longitudinal study found that children's objectively measured PA declined markedly over the transition to adolescence, with over 40 minutes of daily PA being replaced by sedentary time over the 4-year period (Corder et al. 2015). Another review study found that MVPA declines from the age of school entry and recommended that efforts to promote and maintain MVPA in young people should begin in advance of adolescence (Reilly, 2016). A US longitudinal study that objectively assessed 1032 children's PA between 1991-2007 found that children's weekday and weekend day MVPA decreased by 38 minutes and 41 minutes per year, respectively (Nader et al. 2008). A similar pattern has also been reported in other European countries (De Meester et al. 2014b). Recent evidence suggests that VPA experiences greater age-related decline compared to MPA (Corder et al. 2016).

Although boys tend to be more active than girls, there is limited evidence to support gender related PA declines. A systematic review of 26 studies that assessed PA during childhood and adolescence found that children's self-reported PA declined on average by 7% per year and was consistent across boys and girls (Dumith et al. 2011b). A similar pattern has also been found in studies using objective PA measures. For example, a US longitudinal study involving 1032 children reported a large decline in objectively measured MVPA with age and an equal decline for both boys and girls (Nader et al. 2008). More recent studies have reported inconsistent findings. For example, Corder and colleagues (2015) found that UK boys recorded higher MVPA than girls at all ages from age 9-14 years, but their MVPA experienced a much greater declined over time than girls. Conversely, a US study found that between the age of 9 and 15 years after-school PA declined more rapidly in girls compared to boys (Wickel & Belton 2016).

### 2.4.4 Physical activity levels by socioeconomic status

SES is another demographic factor that has been found to negatively influence children's PA (Drenowatz, 2010; Gustafson & Rhodes, 2006). However, the relationship between SES and children's PA is inconsistent with results differing according to SES measures (Biddle et al. 2011a). A systematic review examining the effect of SES on older children's PA reported that only 58% of the 62 included articles found an association between SES and adolescent PA (Stalsberg & Pedersen 2010). A common measure of SES is neighbourhood deprivation. Studies applying area-based SES measures have generally reported no relationship between SES and PA (D'Haese et al. 2014; Pouliou et al. 2015). Although this is the least intrusive measure of SES, it is based on the assumption that there is socioeconomic homogeneity within areas and is unlikely to reflect actual SES compared to individual measures such as household income or parent education (Stalsberg & Pederson, 2010). Cost has been cited as a barrier to lower SES children's participation in structured and organised activities at leisure centres and sports clubs, reducing their opportunities to be physically active (Hardy et al. 2010; Smith et al. 2010). However, while low SES children participate in less organised PA (Cairney et al. 2015; Nielsen et al. 2012; Wijtzes et al. 2014), they tend to record the same overall level of PA as high SES children by means of unstructured PA and free play with friends (Brockman et al. 2009; Voss et al. 2008; Ziviani et al. 2008). Moreover, recent research suggests that socioeconomic gradients in PA only emerge later in life and are less profound during childhood due to the available opportunities for all children to engage in school-based physical education and sport (Ball, 2015).

### 2.4.5 Physical activity levels by time

Some research suggests that PA levels among children and adolescents have declined over recent years (The Health and Social Care Information Centre, 2013; Knuth & Hallal, 2009). The most recent HSE (2012) found a significant decline in the proportion of boys aged 5-15 years meeting current guidelines between 2008 and 2012. Robust evidence though supporting secular declines in child PA is equivocal due in part to limited longitudinal evidence, and inconsistent methods of assessment (Booth, Rowlands & Dollman, 2015; Ekelund, Tomkinson & Armstrong, 2011). Moller and colleagues (2009) found no evidence of a decline in Danish children's objectively measured PA from between 1997/1998 and 2003/2004. There does however appear to be greater evidence supporting declines in specific activity contexts such as active transport (Department for Transport, 2014; Dollman, Norton & Norton, 2005; Garrard, 2009). Prevalence figures for active transport have continued to decline over recent decades with the most recent data suggesting that there has been a further 11% decline from 1995/97 to 2013 (Department for Transport 2014). Although this change is partly due to the growth in car-usage and increased commuting distance between homes and schools, societal changes in attitudes and perceptions towards children walking to school independently are also key contributors (Booth, Rowlands & Dollman, 2015). For example, the percentage of 10-11-year-old English children traveling to school unaccompanied has declined from 94% in 1970 to 47% in 1998 (O'Brien et al. 2000).

There is also strong evidence supporting declines in children's CRF. A publication of 20mSRT data collected between 1964 and 2008 from 25,245,203 9-17-year-olds, across 28 countries, revealed that from 1975 young people's mean 20mSRT performance declined by 13.3% (Armstrong, Tomkinson & Ekelund, 2011). These data though should be interpreted with caution due to differences in protocols and performance metrics used between studies (Catley & Tomkinson, 2013; Tomkinson et al. 2016). It would be plausible to suggest that declines in CRF are the result of decreases in PA levels over time since low PA is associated with lower CRF (Boddy et al. 2014). However, children's 20mSRT performance is also strongly influenced by body mass and fatness (Olds et al. 2006) which has increased globally in recent decades (Olds, 2009), and is thus another likely contributor to the observed decline in 20mSRT performance (Albon, Hamlin & Ross, 2010; Olds & Dollman, 2004). However, declines in 20mSRT performance have also been evidenced in UK children independent of weight status (i.e., BMI) (Boddy et al. 2012; Stratton et al. 2007). Further, declines have been observed in children's muscular fitness. A UK based study that examined changes in English children's muscular fitness over a 10-year period reported significant decreases in sit up (27%), arm strength (26%), and grip performance (7%) (Cohen et al. 2011). Similar declines in hand grip strength have been observed in Canadian children between 1981 and 2007–2009 (Tremblay et al. 2010).

### 2.4.6 Physical activity levels by season

The weather and season are consistent environmental factors that influence children's PA both in the UK and internationally (Carson & Spence, 2010; Rich et al. 2012; Tucker & Gilliland, 2007). Various studies have consistently found that children are more active in the summer (Cooper et al. 2010; Hjorth et al. 2013; Riddoch et al. 2007) and spring (Kolle et al. 2009) compared to winter. These findings are considered to be because the winter months are characterised by reduced daylight hours, lower temperatures, and higher rainfall, thereby limiting opportunities for children to be physically active outdoors (Cooper et al. 2010; Harrison et al. 2015). There is also evidence to suggest that children record higher levels of physical fitness in the summer months relative to winter months (Augste & Kunzell, 2014).

Atkin et al. (2016) found that MVPA was lower in autumn and winter relative to spring in a large-scale UK study involving 7-year-old children. In the same study, seasonal variation was greater at the weekend compared to weekdays. Mattocks et al. (2007a) also reported greater seasonal variability in PA during the weekend compared to weekdays in 11-to-12-year old children. In a longitudinal study involving 64 9-11-year-old children seasonal effects on weekday and weekend PA differed between boys and girls (Rowlands, Pilgrim & Eston, 2009). For boys, weekend activity was similar across seasons but weekday activity was higher in the summer compared to winter, whereas girls' weekday activity was relatively stable across season yet weekend activity was higher in the summer compared to winter. Seasonality and ambient weather conditions may have a more profound effect on boys PA relative to girls as boys typically engage in greater outdoor play than girls (Faulkner et al. 2015; Stone & Faulkner, 2014).

UK research revealed that children's PA is affected more by seasonal daylight changes relative to weather changes (Goodman, Page & Cooper, 2014; Goodman, Paskins & Mackett, 2012). Children in the study were more physically active on long days, partly because they spent more time playing outdoors (Goodman, Paskins & Mackett, 2012). Family PA such as visits to parks may also be influenced more by season when compared to structured forms of activity taking place indoors (Goodman, Paskins & Mackett, 2012). However, there is presently limited research on the context of children's PA by season. Seasonal effects such as increased rainfall do not appear to be associated with active travel to school (Harrison et al. 2015). This may be because for some children they have no other option of travelling to school. There is though some evidence to suggest that seasonal variation in children's PA is influenced by home location and family income (Atkin et al. 2016). Further research investigating seasonal variation in specific activity types, such as active travel, outdoor play and organised sport may help to explain why the seasonal effect varies between population groups. Greater understanding of seasonal effects on children's PA can also better inform the planning and implementation of future PA interventions.

### 2.4.7 Physical activity levels by day of the week

Children are typically less active on weekend days than weekdays (Brooke et al. 2014; Fairclough, Ridgers & Welk, 2012; Rowlands, Pilgrim & Eston, 2008). Children's MVPA was roughly 30% lower on weekend days compared to weekdays in a sample of 626 Canadian children aged 10-15 years (Comte et al. 2013). Moreover, data from an Australian longitudinal study revealed that while 29% of boys and 15% of girls engaged in at least 60 min MVPA on a Monday compared to 39% of boys and 21% of girls on Friday, only 17% of boys and 10% of girls met recommendations on a Sunday (Telford et al. 2013). The school day provides greater opportunity for PA compared to weekend days, creating opportunities to walk to school, play during recess and participate in curriculum and extra-curricular activities (Fairclough et al. 2015; Quarmby & Dagkas, 2010; Uys et al. 2016). As a result, average daily pedometer step counts are known to be higher on school days than on non-school days (Vander Ploeg et al. 2012).

UK children's PA is also known to decline out-of-school hours. In some studies, MVPA accumulated during the school day has accounted for almost two thirds of children's total daily MVPA (Fairclough, Butcher & Stratton, 2008; Ramirez-Rico et al. 2014). In addition, UK longitudinal research found that the greatest decline in children's PA between the ages of 10 and 14 years is at weekends (Brooke et al. 2016). Weekend PA declines are also thought to be more pronounced in low active children compared to high active children (Fairclough et al. 2015). The out-of-school period therefore represents an opportune period to promote PA in children.

## 2.5 IV: Identify factors that influence physical activity (i.e., correlates/determinants)

In light of strong evidence supporting the beneficial effects of PA on children's health, it is important to identify factors that support and restrict PA (Biddle & Mutrie, 2008). PA is a complex behaviour influenced by a broad range of factors. Factors associated with PA participation are generally referred to as PA determinants or correlates (Biddle et al. 2004; 2011). For the purpose of this thesis, the term correlates will be used rather than determinants because correlates are not necessarily determinants of behaviour. Correlate refers to a statistical association between two variables whereas a determinant is as a causal factor (Bauman et al. 2002). Correlate studies are needed to assist in targeting intervention studies to high-risk groups as well as guiding intervention content. Longitudinal studies provide stronger evidence of causality compared to cross-section studies, but randomised controlled trials are considered the gold standard for evidencing cause-effect relationships (Jakes & Wareham, 2003). PA interventions modify factors that influence PA behaviour and it is changes to these mediating variables that in theory lead to an increase in PA levels (Sallis & Owen, 1999).

Effective PA promotion strategies are based upon an understanding of modifiable PA correlates (Sallis et al. 2000; Biddle et al. 2011a). A plethora of studies have examined the correlates of children's PA (e.g., Cadogan, Keane & Kearney, 2014; Cleland et al. 2011; Fairclough, Ridgers & Welk, 2012). The most recent systematic review found 16 correlates that were consistently associated with child PA evidencing such complexity (Sterdt, Liersch & Walter, 2014). Some correlates of PA are non-modifiable but highlight subgroups of the population that can be the target of an intervention study (Bauman et al. 2002). Examples of such correlates include age, sex and SES. It is also important to recognise that PA associations are context specific and can be influenced by mediating, moderating and/or confounding factors (Stanley, Ridley & Dollman, 2012).

### 2.5.1 Confounder

A confounder is a factor associated with the outcome and the exposure (Bauman et al. 2002). For example, age may confound the relationship between outdoor play and PA, with younger children less likely to play outdoors, thus age in this case is associated with the exposure (i.e., PA). However, in contrast to biases introduced by the researcher or the participants such as selection, recall or observer bias, confounding is a form of bias that can be adjusted for in the analysis, using multivariate techniques such as analysis of covariance (ANCOVA) or multivariate analysis of covariance (MANCOVA) when there are several potential confounding factors.

### 2.5.2 Moderator

A moderator is a variable that interacts with the outcome variable varying the strength and direction of the relationship between an independent variable and outcome variable or intervention programme and intervention outcome (Bauman et al. 2002). For example, gender may moderate the relationship between parental support and children’s PA resulting in different effect estimates for boys and girls. This is also referred to as an interaction and can be overcome by stratifying the data by the moderator (i.e., gender), so that the association between parental support and PA is examined for both boys and girls separately.

### 2.5.3 Mediator

A mediator is an intervening variable that plays an important role in the cause-effect link between an independent and outcome variable or between an intervention programme and intervention outcome (Bauman et al. 2002). For example, children’s self-efficacy may mediate the relationship between parental support and children’s PA (Lubans, Foster & Biddle, 2008).

### 2.5.4 Youth Physical Activity Promotion Model

Theoretical models are used as a framework to understand the many factors that enable or restrict PA participation. Ecological models of health behaviour provide a comprehensive conceptual framework for research on PA. The socio-ecological model postulates that health related behaviour is influenced by a multitude of individual, social and environmental factors, and for behaviour change to occur at a population level, it is essential that all levels of influence are addressed simultaneously to support self-regulation (Nigg & Paxton, 2008). The model recognises that while it is important to provide individuals with the skills and the motivation to change their health behaviours, it is also essential that the environment and policies make it convenient, attractive, and economical for the individual to choose healthful behaviours (Sallis, Owen & Fisher, 2008). Because children are motivated and influenced by factors different to adults a theoretical model that accounts for the developmental, psychological and behavioural characteristics is necessary to investigate child PA.

The Youth Physical Activity Promotion Model (YPAPM) (Welk, 1999; Figure 2.3) is a conceptual framework used to improve understanding on factors that may predispose, reinforce or enable children's PA. The YPAPM follows a hierarchical structure and categorises child PA correlates as; predisposing (enjoyment, self-efficacy and perceived competence), enabling (e.g., fitness, environment), and reinforcing factors (e.g., parents and peers). Demographic factors such as; age, gender and SES have a direct effect on how other factors in the model (e.g., predisposing, enabling, reinforcing) influence young people's PA and subsequently are positioned at the base of the model (Welk, 1999). Predisposing factors refer to psychological variables including self-esteem, perception of competence, attitudes towards PA and enjoyment of PA, and collectively, increase the likelihood that a young person will be physically active. The predisposing category encompasses two separate questions, 'Is it worth it?' and 'Am I able?' in an attempt to reduce PA behaviour. The 'Is it worth it?' component addresses the cost/benefit assessment of participating in PA, including; attitudes, beliefs and enjoyment, whereas, the 'Am I able?' component addresses self-efficacy and perceptions of competence (Welk, 1999).

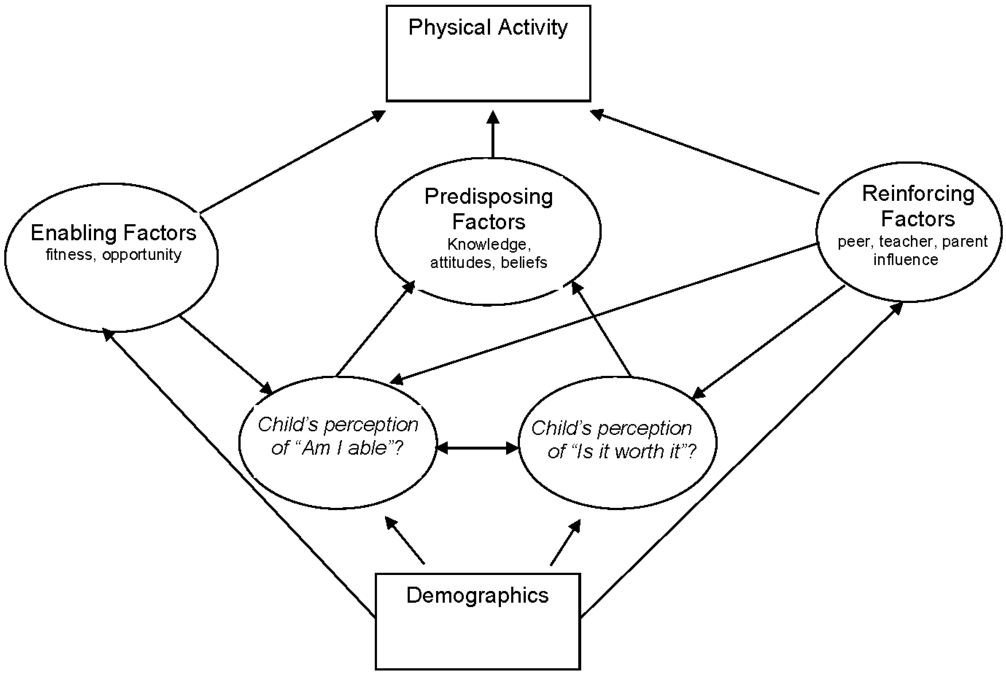



Figure 2.3 A conceptual diagram of the YPAPM (Welk, 1999)

Reinforcing factors relate to the social environment and specifically the influence of peers and parents. Parents are a strong influence on children's PA (Gustafson & Rhodes, 2006; Mitchell et al. 2012). They can serve as PA role models and provide various sources of social support (Beets, Cardinal & Alderman, 2010; Duncan, Duncan & Strycker, 2005). Further, parents play a fundamental role in shaping the beliefs, attitudes and values of their children through the attitudes and beliefs that they exhibit and thus have been shown to influence children's perceptions of PA (Bois et al. 2005; Zecevic et al. 2010). Enabling factors refer to environmental and biological correlates (Welk, 1999). Enabling factors include variables such as fitness, access to provision and environmental factors. The YPAPM is a suitable framework for this thesis. The model's support of multiple theoretical perspectives enables the investigation of a broad range of consistently reported child PA correlates (Sterdt, Liersch & Walter, 2014), and the variables of interest reflect the enabling, reinforcing, predisposing, and demographic factors contained in the model.

The promotion of PA in young people has become a public health priority for Governments around the world (World Health Organization, 2012). A broad range of factors contribute to children's low levels of PA including low self-esteem (Welk & Eklund, 2005), self-efficacy (Van der Horst et al. 2007) and perceived competence (Fairclough & Ridgers, 2010), limited social support from parents (Beets, Cardinal & Alderman, 2010; Tandon et al. 2014) and peers (Jago et al. 2009a; 2011), as well as a pervasive technology-saturated culture that promotes extended periods of sitting and discourages traditional incidental forms of activity such as outdoor play (Gleave, 2009; Gleave & Cole-Hamilton, 2012; Witherspoon & Manning, 2012) and active travel (Carver, Timperio & Crawford, 2013; Mammen et al. 2012). Environmental factors are also key barriers to children's PA, particularly those that influence parental perceptions of neighbourhood safety such as traffic volume and 'stranger danger' and in turn limit children's opportunities to be active outdoors independent of adult supervision (De Meester et al. 2014a; D'Haese et al. 2013; Jenkins, 2006).

#### 2.5.4.1 Enabling factors

Socioecological models postulate multiple environmental influences on child PA (Sallis et al. 2006). The neighbourhood environment is a key setting for child PA (Aarts et al. 2012; Loebach & Gilliland, 2016). Supportive neighbourhood environments are important for PA because they provide opportunities and infrastructure for structured and unstructured modes of PA, including outdoor play and travel behaviours (e.g., walking and cycling to and from school; Timperio, Reid & Veitch, 2015). Several studies have found that children living near parks, playgrounds, and recreation areas record higher levels of MVPA (Almanza et al. 2012; Bancroft et al. 2015; Ward et al. 2016) than children living further away from these areas. There are a range of other environmental attributes that are known to influence child PA. In a comprehensive review of 65 studies reporting associations between the built environment and child PA, PA was most consistently associated with walkability, land-use mix, residential density, traffic speed, and access or proximity to recreation facilities (Ding et al. 2011).

To date, reported associations between environmental attributes and child PA have been inconsistent. Although several factors may have contributed to the statistical heterogeneity across studies, methodological diversity is considered a key contributing factor (Ding et al. 2011). Previous studies have used a range of subjective and objective measures to assess neighbourhood attributes (McGrath, Hopkins & Hinckson, 2015; Reimers et al. 2013). Objective methods quantify neighbourhood attributes using audits and spatial data whereas subjective methods assess neighbourhood attributes using self-report surveys and participant perceptions of the environment. Various studies have employed subjective rather than objective methods (Fueyo et al. 2016; Garcia-Cervantes et al. 2016; Roberts et al. 2016; Salmon et al. 2013) in the view that the perceived environment is likely to more directly relate to a child's PA behaviour than objectively measurable environmental attributes (Ball et al. 2008). The Neighborhood Environment Walkability Scale-Youth (NEWS-Y) developed by Rosenberg et al. (2009) provides an empirically derived measure of various aspects of the built environment that may relate to child PA. The NEWS-Y assesses parent perceptions of the neighbourhood environment, and has been used to investigate associations with child PA (Kneeshaw-Price et al. 2013). The NEWS-Y scale has been used in the USA but has been seldom used in the UK.

The evidence base describing the interplay between environmental attributes and child PA relies on cross-sectional quantitative data (Timperio, Reid & Veitch, 2015). Indeed, few qualitative studies have explored parental perceptions of neighbourhood attributes (Eyre et al. 2014; Teedon et al. 2014) and even fewer have consulted with children (Fitzgerald, Bunde-Birouste & Webster, 2009). Additional qualitative research with children and parents may provide insight into neighbourhood attributes deemed most relevant by children and parents that could be targeted for change in interventions to increase children's independent mobility, outdoor play and active travel.

Few experimental studies have tested the efficacy of modifying environmental attributes to increase child PA, partly due to methodological challenges (Ding et al. 2011). Of the few environmental intervention studies, some have reported positive intervention effects. For example, D'Haese and colleagues (2015b) found that the introduction of a safe play space within urban neighbourhoods resulted in increases in children's MVPA levels. Another study reported an increase in overall PA following renovations to the playfields of two urban parks, one with and one without programme changes targeting family and youth involvement (Tester & Baker, 2009). However, further policy relevant experimental evidence is needed to advance the evidence base.

### 2.5.4.2 Reinforcing factors

Parents can influence their children's PA through a variety of mechanisms. Parental PA and parent-child PA are consistently associated with higher child PA (Madsen, McCulloch & Crawford, 2009; Verloigne et al. 2012). Jago et al. (2014) found that 5-6-year-old children were 50% and 33% more likely to meet PA guideline recommendations on weekdays and weekend days, respectively, if their mother met the adult recommendation compared with children whose mother failed to meet the recommendation. There is also evidence to suggest that parent PA has a positive influence on children's long-term PA (Madsen, McCulloch & Crawford 2009). An Australian longitudinal study found that parental PA role modelling and parent-child co-participation were the strongest predictors of children's PA (Crawford et al. 2010). Children's out-of-school sports participation (Cleland et al. 2005), cardiorespiratory fitness (Cleland et al. 2005; Martin-Matillas et al. 2012), and independent mobility (Santos et al. 2013) have also been positively associated with parent PA. The influence of parent PA on child PA is considered more influential during early childhood rather than late childhood (Yao & Rhodes, 2015), and when both parents are active (Fuemmeler, Anderson & Masse, 2011).

According to recent review studies the parent-child PA relationship is far from consistent (Biddle et al. 2011a; Yao & Rhodes, 2015). Research in this area is limited by predominantly cross-sectional study designs and limited use of objective methodologies (Belanger-Gravel et al. 2015; Janssen, 2015). Moreover, previous studies have tended to focus on parents' overall PA levels including work-related activity rather than the type and context of parent PA (i.e., leisure-time). Parents' leisure-time PA (e.g., running, swimming, gym use) may be a more appropriate measure of direct parental PA influence given that parent work-related PA (e.g., manual labour) is likely to go unnoticed by children (Saelens & Kerr, 2008).

Parent-child co-participation may also be a stronger predictor of child PA compared to parental PA (Cleland et al. 2011). The weekend provides the greatest opportunity for family-based PA due to children's non-attendance at school and parents' reduced work responsibilities. There is limited information however on children's and family-based PA during the weekend as previous studies have generally focused on weekday (Pearce et al. 2014) or total week relationships (Lee et al. 2010). Examining the weekend period specifically may present a more detailed understanding of children's out-of-school and family-based PA and inform future PA intervention strategies targeting children. Moreover, it is reasonable to suspect that both family-based PA and the parent-child PA relationship varies according to time of year, given that children's PA (Goodman, Paskins & Mackett, 2012; Hjorth et al. 2013; Riddoch et al. 2007) and time outdoors (Cooper et al. 2010) is generally higher in the summer months, owing to increased daylight hours and relatively lower precipitation levels compared to the winter months. However, there is a dearth of research examining seasonal effects on family-based PA.

Parents also influence children's PA by providing sources of support (Beets, Cardinal & Alderman, 2010). Trost et al. (2003) found that parental supportive behaviours including transporting children to areas to be physically active, watching children participate in PA, and verbally praising and encouraging children to be physically active were more influential on children's PA behaviour relative to parent's activity levels. Cross-sectional (Beets et al. 2006, 2007; Hohepa et al. 2007; Harrington et al. 2016; Loprinzi & Trost, 2010; Lau et al. 2015; Pyper, Harrington & Manson, 2016; Schoeppe & Trost, 2015; Springer, Kelder & Hoelscher, 2006) and longitudinal studies (Bauer et al. 2008; Dowda et al. 2007; Ornelas, Perreira & Ayala, 2007) have described positive associations between parental support (i.e., encouraging children to be active, praising participation and facilitating children's involvement in PA through transporting children to areas to be active as well as purchasing equipment and paying subscription fees) and children's PA.

There is evidence to suggest that the type and amount of parental support provided to children differs between mothers and fathers (Beets et al. 2007; Brunet et al. 2014). In a study involving one hundred and eighty 9-year-old girls and their parents, mothers provided greater levels of logistic support (i.e., making arrangements for children to be physically active and taking them to and from activities) to children, whereas fathers used their own behaviour to encourage PA through doing activities with children and being physically active themselves (Davison, Cutting & Birch, 2003). These findings concur with previous research, which revealed that children's PA is strongly influenced by their father's PA levels (Ferreira et al. 2006; McMinn et al. 2008). Further, Maatta and colleagues (2014) found that father's PA had a direct effect on Scandinavian children's PA, whereas encouragement, mother PA, and involvement had an indirect effect on children's PA through perceived competence and attraction to PA. This may explain why some studies have reported lower levels of PA in children living in families with no father present (Gorely et al. 2009; Quarmby, Dagkas & Bridge, 2011). Although in contrast, other studies have found children from single parent families to be just as active as youth from two parent families when the present parent is highly active (Gustafson & Rhodes, 2006) and when a high level of PA encouragement is provided to them (Hohepa et al. 2007).

Parents also influence children's PA indirectly through the restrictions they place on their children's PA. For example, though time spent outdoors is consistently shown to increase daily PA in children (McMinn et al. 2013; Nilsson et al. 2009b), parents often limit children's levels of outdoor play in response to concerns about their child's safety (road safety and 'stranger danger') (Carver, Timperio & Crawford, 2008; Veitch, Salmon & Ball, 2010), even when children report positive perceptions of the local neighbourhood (Timperio et al. 2004). Qualitative research undertaken in the UK found children's opportunities to be active outdoors on their own are mostly limited by parental safety concerns regarding the proximity of friends, road traffic and threat of crime or attack from strangers (Jago et al. 2009b). Cross-sectional research carried out in Australia has shown that restrictive behaviour by parents resulted in lower levels of active transport and MVPA outside school hours for both boys and girls (Carver et al. 2010). Moreover, restricting children to the confines of the home environment is likely to encourage the adoption of sedentary behaviour rather than active behaviours, given that recent UK based research found that girls engaged in greater levels of sedentary behaviour when parents restricted their outdoor play (Atkin et al. 2013).

However, most of the research in this area has focused on built environmental influences rather than social environmental influences. Further research is warranted to explore the influence of the social environment on child PA.

Aside from parental perceived risk attributed to motorised traffic and ‘stranger danger’ there may also be social influences that drive parents’ decision making towards allowing their children to play outdoors (Lacey, 2007; Little, 2015; Stolle & Nishikawa, 2011). One key factor that has contributed to the decline in children’s outdoor play is the seemingly improved availability of out-of-school provision. This has dramatically changed the out-of-school spatial activity patterns of children (Loebach & Gilliland, 2016). Instead of playing outdoors children are typically enrolled in structured, adult led activities (Gray, 2011; Skar & Krogh, 2009; Tremblay et al. 2007), access to which is highly dependent on social and economic capitals such as parental income, neighbourhood residence and family structure. Consequently, such activities may place some children at a disadvantage (Collins, 2003). However, further research is needed to explore associations between children’s PA levels and neighbourhood residence.

#### 2.5.4.3 Parent physical activity knowledge

Children’s PA encompasses a broad range of activities and takes place in a variety of settings (Payne, Townsend & Foster, 2013). Consequently, it may be difficult for parents to make an accurate judgement about the amount of time their children are physically active each day (Kremers et al. 2008). Research suggests that many parents overestimate their children’s PA levels (Corder et al. 2010, 2012; Hesketh et al. 2013) and misperceive their child’s weight status (Remmers et al. 2014b). Parents tend to overestimate their children’s PA level if they consider their child to be of healthy weight (i.e., slim physique) (Corder et al. 2010).

Parents that misperceive their child to be sufficiently active and of healthy weight are unlikely to encourage their children to engage in more PA (Sawyer et al. 2014). This could have implications on PA promotional strategies, as such parents may not see the relevance or need to change their supportive behaviours towards their children’s PA

(Faulkner et al. 2014). Parental knowledge of child PA recommendations is associated with higher levels of parent PA support and encouragement, but many UK parents are unaware of the recommended daily PA guidelines for children (Sawyer et al. 2014). Strategies to address parental PA overestimation and increase awareness of PA guidelines as well as ways in which to measure activity levels may be an important consideration for future intervention design. Moreover, when endorsing PA, it may resonate more effectively with parents if communicated in the context of positive child development, wellness, and enhancement of broader health outcomes such as self-esteem (Ahn & Fedewa, 2011) and academic attainment (Singh et al. 2012).

## 2.6 V: Evaluate physical activity interventions to change physical activity behaviour

Childhood is an important developmental stage during which health behaviours including PA are established (Marmot, 2010; Telama, 2009). Promoting PA during childhood is therefore essential. To date, PA promotion efforts have generally been school-based (Burke et al. 2014; Van Kann et al. 2016). These interventions have modified the school environment (i.e., school playground) (Crust et al. 2012; Ridgers, Fairclough & Stratton, 2010), re-designed physical education teaching practices and lesson content (Humphries & Ashy, 2013; Fairclough et al. 2013), delivered after-school PA programmes (Beets, Huberty & Beighle, 2013; Crouter et al. 2015; Gortmaker et al. 2012; Weaver et al. 2015), and facilitated active school travel (Østergaard, Støckel & Andersen, 2015; Sayers et al. 2012). While some of these promotional efforts have been effective, many have provided small to modest effects (Kriemler et al. 2011; Lai et al. 2014; Metcalf, Henley & Wilkin, 2012; Russ et al. 2015). It is also important to note that school-based intervention studies typically assess PA within limited time periods (i.e., after school, travel time or playtime) and fail to account for potential PA compensation (Brazendale et al. 2015; Ridgers et al. 2014; 2015). Failing to assess whole day PA level and maintenance limits the ability to assess long-term behavioural change (Aarts, Paulussen & Schaalma, 1997; Lally et al. 2010).

Socio-ecological models of health promotion postulate that children's health behaviours are shaped by the setting in which they occur for which the school setting is only one (Sallis, Owen & Fisher, 2008). The family is a key environment that shapes children's health behaviours, particularly their PA by shaping norms, providing PA opportunities, and placing constraint on individual choice (i.e., independent mobility and sedentary time) (Crawford et al. 2010; Institute of Medicine, 2003). As such, children's PA attitudes and experiences are largely founded upon family PA values and attitudes combined with the level of family investment given to PA (Ball, 2010; Dagkas & Quarmby, 2012) and support provided to them by their parents (Beets, Cardinal & Alderman, 2010; Gustafson & Rhodes, 2006; Mitchell et al. 2012). Given the strong socialising effect of parents on children's PA, family-based PA interventions could serve as a promising alternative compared to traditional school-based approaches. Surprisingly few PA intervention studies have included parents in some capacity (Kader, Sundblom & Elinder, 2015; O'Connor, Jago & Baranowski, 2009). Parents are in a unique position to influence the PA levels of their children serving as PA 'gate keepers' and 'choice architects' (Thaler & Sunstein, 2008, Maitland et al. 2013; 2014). Parents can therefore serve three key roles in a family-based intervention programme. They can provide support, role model positive health behaviours, and set limits on behaviours unconducive to health (Ward, Saunders & Pate, 2007).

A review study of family-based interventions targeting children's food and activity behaviours found that interventions with greater parental involvement and those where parents were responsible for implementation were most effective (Golley et al. 2011). Similarly, a more recent systematic review study of family-based RCT's targeting sedentary time found that parental intervention involvement was a key determinant of intervention success with studies including a high-level parental component consistently associated with significant improvements in children's sedentary time (Marsh et al. 2014). Moreover, positive intervention effects have been observed in various family-based obesity intervention programmes (Campbell et al. 2013; French et al. 2011; Rodearmel et al. 2006; Sacher et al. 2010; Salminen et al. 2005; Todd et al. 2008). A systematic review of family-based childhood-obesity RCTs reported that in all included studies (n=15) family inclusion played an important role in modifying the lifestyles of overweight children (Sung-Chan et al. 2013).

There has been mixed evidence supporting the effectiveness of after-school PA interventions at increasing MVPA in children (Mears & Jago, 2016). The highest peaks of PA within a day have been recorded in the after-school period (Riddoch et al. 2007). Therefore, the after-school period may not be the most suitable time to deliver interventions to increase children's overall daily MVPA levels. Furthermore, the early evening is generally when sport and active-leisure activities take place (De Baere et al. 2015). Delivering interventions during periods of high activity and provision availability is unlikely to result in overall increases in daily MVPA. A more promising alternative is to target specific groups of children during the out-of-school period such as those that are inactive or do not attend structured provision (Jago et al. 2010b). PA interventions may also be more effective when delivered at the weekend. The weekend is characterised by low activity and the disparity in activity levels between low and high active groups widens (Fairclough et al. 2015). However, the evidence based on children's weekend PA and family-based PA is limited. Families are considered a difficult group to engage with and support. Aside from the challenges of recruiting families into health intervention, methodologically, little research exists on effective ways in which to engage parents in intervention design (O'Connor, Jago & Baranowski, 2009; van Sluijs & Kriemler, 2016).

The evidence base on the effectiveness of family-based interventions on child PA is inconsistent. Aside from a few intervention studies (Epstein et al. 2008; Todd et al. 2008), the majority have reported a null intervention effect (Dellert & Johnson, 2014). A systematic review of PA interventions delivered in family and community settings reported that between 2007 and 2011, six family-based and four community-based interventions were delivered but few had a positive effect on children's PA (van Sluijs, Kriemler & McMinn, 2011). A more recent review study of family-based interventions reported that sixty-six percent of the forty-seven included studies had a positive effect on children's PA (Brown et al. 2016). The review recommended that future family-based interventions should be tailored to the context within which they are delivered and the time constraints of the family. Traditionally, family-based PA interventions have delivered activity sessions or workshops to families and examined whether PA or health related outcomes have improved between baseline and post intervention (Anand et al. 2007; Escobar-Chaves et al. 2010; Monteiro, Jancey & Howat, 2014; Milton et al. 2011). This approach can present practical barriers (i.e., transport, work schedules and competing demands on family time) to reaching parents (Holt et al. 2015; Lucas et al. 2014), who are already a difficult group to engage with and support (Davis, McDonald & Axford, 2012; O'Connor, Jago & Baranowski, 2009). This can further influence recruitment and attrition rates particularly among those living in less favourable socioeconomic circumstances, arguably the ones most in need of health intervention (Arai et al. 2015; Dhaliwal et al. 2014; Fagg et al. 2014).

Generally, only a small number of short duration activity sessions are delivered during family-based intervention programmes, which may not provide a realistic time-period for PA behavioural change**.** This approach can also lead to a dependency on the programme itself and therefore may have implications on long-term behavioural change post intervention delivery (Moore, Moore & Murphy, 2011). In the context of families, PA behaviour change requires children and parents to exert considerable conscious effort to change established habits which is difficult to achieve and maintain in an environment that is unsupportive of active living (NICE, 2007; Ryan, 2009). This challenge is also acknowledged by intervention participants (Lucas et al. 2014; Newson et al. 2013). The extent to which children's and parents' PA is sustained following the delivery of family-based intervention programmes is unknown with few examining the long-term impact of the intervention programme on habitual PA (van Sluijs & Kriemler, 2016).

Parents may perhaps prefer more flexible intervention programmes such as online materials or activities that can be completed at home or in the neighbourhood with their children (Holt et al. 2015). Promoting parent PA and parent-child PA, particularly during out-of-school hours could be an effective way to influence parental involvement in interventions to increase children's PA. A recent US family-based intervention study found that an increase in maternal and paternal step counts significantly predicted an increase in child step counts (Holm et al. 2012). Similarly, another US study that assessed children's PA in a controlled setting under 3 experimental, social conditions: alone, with a parent watching, and participating in activity with parent, found that that the parent-child participating condition had the greatest influence on children's PA (Rebold et al. 2015). Providing families with feedback on their PA and facilitating PA self-monitoring may help to increase parent-child PA. Activity monitors such as pedometers provide individualised feedback reflecting ambulatory PA and serve as a tool to self-monitor and set personalised goals. This approach of combining self-monitoring and goal setting is consistent with Self-Regulation Theory whereby families regulate their PA by comparing it with an identified goal (Bandura, 1991). Brown et al. (2016) found that the combination of goal setting and reinforcement is consistently associated with higher levels of participant motivation in family-based PA interventions, and recommended further use in future family-based PA interventions.

Other family-based PA interventions have adopted an educational approach and centred on changing parental attitudes towards PA, which may not be appropriate for all families (Cohen et al. 2013; Salmon, 2010; West et al. 2010). For example, some parents may value a physically active lifestyle and possess positive attitudes towards PA, both at an individual and a family level, but face difficulty translating intention into action (i.e., PA support) (Hamilton & White, 2011; 2012; Rhodes et al. 2015). For these parents, interventions focusing on improving parental PA attitudes and PA support are unlikely to be effective. An alternative approach could be to facilitate family PA regulation by enhancing behavioural planning skills so that parents are more confident and able to link their intentions with sustained PA support and family PA (Butson et al. 2014; Gollwitzer & Sheeran 2006). Rhodes, Naylor and McKay, (2010) provided evidence for the effect parents' planning and regulatory capabilities have on family PA levels. The intervention group in this study were provided with family PA planning materials consisting of educational information regarding how to plan for family PA and also practical materials including calendars and fridge magnets to create a plan. The intervention group reported significantly higher levels of family PA compared to the control group after the intervention.

Promoting family-based PA without considering PA social norms, resources and opportunities, and neighbourhood environmental barriers such as crime and traffic is unlikely to facilitate positive sustained behaviour change (Institute of Medicine, 2001; 2003). Rather, interventions informed by an understanding of family experiences and ecology, and account for individual needs and constraints, have greater potential to facilitate positive PA parenting practices and in turn improve children's PA and health outcomes (Kipping, Jago & Lawlor, 2012; Lampard et al. 2013). Few intervention studies for children and families have sought or integrated the views of the target group in the design of the intervention programme (Brown et al. 2016; van Sluijs & Kriemler, 2016). A recent US child obesity pilot intervention that included parents in the design and implementation of the intervention found that parents' self-efficacy to promote healthy eating in children and their level of support for children's PA significantly increased post intervention (Davison et al. 2013). Adopting a similar approach, for example, consulting with parents in a formative sense and empowering parents to play an equal role in intervention design and implementation could provide an effective approach to family-centred PA promotion. Few PA intervention studies though have engaged with families prior to intervention delivery (Bentley et al. 2012; Davison et al. 2013; Jago et al. 2012). Failing to undertake prior formative work may influence the relevancy of the programme to participants and may impact on participant engagement and intervention outcomes (Visram, Hall & Geddes, 2013).

In summary, exploring the attitudes, norms, and perceptions of families, and consulting with them in a formative sense to that of intervention design is central to a phased approach to complex intervention development, and deemed essential to their success (Craig et al. 2008; Davison et al. 2013). Although some studies have explored family-based PA intervention recruitment and retention strategies (Bentley et al. 2012; Brown, Schiff & van Sluijs, 2015; Jago et al. 2012), little consideration has been given to parents' concurrent PA knowledge or perceptions which may also have important implications on perceived intervention relevance, uptake, and design. Moreover, research to increase PA in children (De Lepeleere et al. 2013; O'Connor & Brown, 2013; Zahra, Sebire & Jago, 2015) and inform intervention design has largely been based upon parental views and underrepresented children's voices (Bentley et al. 2012; Jago et al. 2012). Consulting with children and parents prior to familial PA intervention, eliciting their perspectives on PA and intervention content will enable intervention content to be aligned with family-specific perceptions and needs, and may help to overcome key intervention challenges including recruitment and engagement. In light of the limitations of previous interventions, there is a need for further mixed methods formative research with children and parents to explore their perceptions of out-of-school PA and offer formative opinion about future intervention design.

### 2.7 Summary of literature

The literature review has highlighted the importance of PA to children's short and long-term health, and established the need for context specific interventions to increase PA in children. Evidence regarding successful approaches to increase children's PA remains equivocal, and is principally limited to that of school-based approaches. Interventions targeting periods of high inactivity such as the out-of-school period present an opportune time to promote PA among children. Current evidence suggests that family-based PA interventions represent a potentially valuable route to increasing children's out-of-school PA. However, little is known about children's out-of-school and family-based PA. Further understanding into the characteristics of out-of-school PA among families may help inform the design of future family-focused PA interventions.

## 2.8 Aims of thesis

**Study 1 objectives**

- To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation.
- To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.

**Study 2 objectives**

- To assess children's physical activity levels derived from wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data.
- To examine the comparability of physical activity levels between the two devices throughout the segmented week.

**Study 3 objectives**

- To use a novel combination of qualitative techniques to explore children’s current views, experiences and perceptions of out-of-school physical activity as well as offering formative opinion about future intervention design.

**Study 4 objectives**

- To explore parents' physical activity knowledge and perceptions of children’s out-of-school physical activity to formatively contribute to a family-based intervention design.

**Study 5 objectives**

- To investigate the stability of weekend MVPA among target children, siblings, and parents using repeated measures raw accelerometer data.
- To offer contextual insight into the characteristics of weekend PA amongst one representative low active family and one high active family.

**Thesis Study Map**

A thesis study map appears at the beginning of each chapter to highlight the key objectives and findings of the studies, and to clarify where each study fits in the overall thesis.

| **Study** | **Objectives and key findings** |
|---|---|
| Study 1: Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children | **Objectives:**<br><br>(1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation.<br><br>(2) To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group. |
| Study 2. Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week. | |
| Study 3. Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity. | |
| Study 4. Parental perceptions on children’s out-of-school physical activity and family-based physical activity. | |
| Study 5. Context matters! Sources of variability in weekend physical activity among families: A repeated measures study. | |

# Chapter 3

# General methods

## General methods

### 3.1. Introduction

The purpose of this chapter is to describe the common methods used throughout the thesis. Any additional methods and procedures specific to a study will be described in the relevant chapter where they were applied. All measures were carried out by the lead researcher. In some instances, data collection was supported by trained research assistants.

### 3.2. Preliminary information

All studies received ethical approval from Liverpool John Moores University ethics committee (Study 1 and 2, ref 13/SPS/048, study 3 and 4, ref 14/SPS/033; study 5, ref 15/SPS/023). All studies obtained informed parental consent and participant assent, and all parents/carers completed medical screening forms on behalf of their child prior to commencement of study 1.

### 3.3. Anthropometries

Stature and sitting stature were measured to the nearest 0.1 cm using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, UK). Leg length was calculated by subtracting sitting stature from stature. Body mass was measured to the nearest 0.1 kg using calibrated scales (Seca, Birmingham, UK). Body mass index (BMI) was calculated from stature and body mass as a proxy measure of body composition ($kg/m^2$), and BMI z-scores were assigned to each child (Cole et al. 1995). Age-specific and sex-specific BMI cut-points were used to classify children as normal weight or overweight/obese (Cole et al. 2000). Waist circumference was measured at the midpoint between the bottom rib and the iliac crest to the nearest 0.1 cm using a non-elastic measuring tape (Seca, Birmingham, UK).

### 3.4. Maturation

Gender-specific regression equations were used to predict children's age from peak height velocity (Mirwald et al. 2002). This calculation was used as a proxy measure of biological maturation. The method is non-invasive, and has demonstrated acceptable agreement when correlated against skeletal age (*r* = 0.83) (Mirwald et al. 2002). The equations for boys and girls are presented below.

Boys:

Maturity Offset = -9.236 + [0.0002708 x (leg length x sitting stature)] + [0.007216 x (age x sitting height)] + [0.2292 x (body mass: stature ratio)].

Girls:

Maturity Offset = -9.376 + [0.0001882 x (leg length x sitting stature)] + [0.0022 x (age x leg length)] + [0.005841 x (age x sitting stature)] + [0.002658 x (age x body mass) + [0.07693 x (body mass: stature ratio)]

**3.5 Self-reported physical activity**

PA was assessed using the Physical Activity Questionnaire for Older Children (PAQ-C) (Kowalski, Crocker & Donen, 2004). The PAQ-C is a valid and reliable measure of general PA levels (Crocker, Bailey & Faulkner, 1997; Kowalski, Crocker & Faulkner, 1997), and is considered a suitable tool for PA surveillance in young people (Biddle et al. 2011b). The questionnaire comprises nine items assessing PA at various times of the week. Each statement is scored on a five-point scale ranging from low (1) to very high levels of activity (5), with the overall PAQ-C score calculated as the mean of the nine PA items (Kowalski, Crocker & Donen, 2004).

**3.6 Cardiorespiratory fitness**

CRF was assessed using the Sports Coach UK 20 m multistage shuttle run test (20mSRT) (Leger et al. 1988). Children completed 20m shuttle runs keeping in time with an audible ‘bleep’ signal. The time between bleeps progressively decreases, increasing the intensity of the test. Children were encouraged to run to exhaustion, and the number of completed shuttles was recorded for each participant. The total number of completed shuttles was retained for analysis. This assessment was conducted in school playgrounds.

### 3.7 Area-level deprivation

Area-level deprivation was calculated using the 2015 Indices of Multiple Deprivation (IMD) (Department for Communities and Local Government, 2015). The IMD is a UK Government produced measure comprising 7 areas of deprivation (income, employment, health, education, housing, environment, and crime). Deprivation scores were generated using the National Statistics Postcode Directory database and parent reported home postcodes. Higher SES was represented by lower deprivation scores.

# Chapter 4

# Study 1:

# Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children

The main outcomes of this study have been published in *BMJ Open*: Noonan, R. J, Boddy, L. M., Knowles, Z. R., & Fairclough, S. J. (2016). Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. *BMJ Open 6*, e008693. The published article can be found in Appendix A.

### 4.1 Introduction

In line with other developed countries, the UK Government agencies highlight the need for children to accumulate at least 1 hour of MVPA each day, and reduce time spent in sedentary behaviours (Chief Medical Officers, 2011). Current UK PA prevalence data, however, suggests that most children fail to achieve PA guidelines, and that, though figures vary between measurement approaches, activity levels are often lowest among high-deprivation children (Griffiths et al. 2013; Public Health England, 2014). However, comparatively few studies use an area-level measure of deprivation, and reported associations between deprivation and children's PA have generally been based on data from the USA (Drenowatz et al. 2010; Tandon et al. 2012) and Australia (Ball et al. 2009; Dollman & Lewis, 2009; Ziviani et al. 2008) which limits generalisation to children in the UK.

Children residing in areas of high-deprivation are more likely to be exposed to neighbourhood and home environments that are unconducive to PA due to increased neighbourhood safety concerns (Kaushal & Rhodes, 2014), and a lack of home features such as gardens or backyards (Tandon et al. 2012). Liverpool is the sixth largest city in England and is ranked as the most deprived, with over 90% of Liverpool's 471 000 population living in areas of high-deprivation (Department for Communities and Local Government, 2015). The disproportionate health inequalities of the city's inhabitants are reflected in the below average life expectancy of Liverpool adults, and the 23.7% obesity rates among children aged 10–11 years which exceed the national average of 19.1% (Public Health England, 2015). Little though is known about the relationships between home and neighbourhood environments, and health variables and behaviours of children living in this deprived community. Further information on how these factors influence children's health could inform future health-promotion strategies designed to improve health outcomes in children from deprived communities. Moreover, stratifying analyses and investigating associations by indices of multiple deprivation (IMD) level may present a clearer picture as to potential target areas for future population-specific intervention studies. This study, therefore, aimed (1) to investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation and (2) to assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.

## 4.2 Study specific methods

### 4.2.1 Participants and setting

Participants were Liverpool schoolchildren aged 9–10 years. Of the 125 primary schools in Liverpool, 76 were provided with information regarding the study and were invited to participate. Eleven schools expressed an interest and 10 schools (13.6%) agreed to take part, of which seven were located in areas of high-deprivation (Department for Communities and Local Government, 2015). All children ($n$ = 549) aged 9–10 years in participating schools received a survey pack which contained parent and child information sheets, consent and assent forms, a parental questionnaire, and medical screening form. Completed informed parental consent and child assent were returned from 217 children (39.5% response rate). The ethnic origin of the consenting children was 84.1% white, which reflects the ethnic demography of the city's school-age population. Data were collected between January and April 2014.

### 4.2.2 Measures and procedures

#### 4.2.2.1 Area-level deprivation

Area-level deprivation was calculated using the 2015 IMD (Department for Communities and Local Government, 2015), as described in Section 3.7 of General methods Chapter 3. The mean IMD score for England is 23.64, and the IMD cut-off value for the most nationally deprived tertile is 26.83, which was lower than the IMD scores of 68% of the study sample. Therefore, a 50th centile IMD score of 35.63 was calculated for the sample, and one IMD median-split categorical variable was created to provide two groups to represent children living in areas of high-deprivation (median IMD score 49.76) or high-to-medium deprivation (median IMD score 22.86).

The research team visited schools to carry out anthropometric measurements, fitness assessments and administer questionnaires to children in classrooms. The children were informed that the questionnaires were not tests, and were asked to answer all questions as honestly as possible, not to confer with others, and to ask a researcher if they were unsure about any of the questions. Parental questionnaires were completed at home and returned to the school along with the consent forms.

#### 4.2.2.2 Health-related variables

##### 4.2.2.2.1 Physical activity and cardiorespiratory fitness

PA and CRF were assessed using the PAQ-C (Kowalski, Crocker & Donen, 2004) and 20mSRT (Leger et al. 1988), respectively, as described in General methods, Chapter 3, Section 3.5 and 3.6.

##### 4.2.2.2.2 Anthropometrics and maturation

Stature, sitting stature, body mass, BMI, BMI z-scores and waist circumference were assessed as described in General methods, Chapter 3, Section 3.3. Somatic maturation was calculated using the Mirwald equations (Mirwald et al. 2002) as described in General methods, Chapter 3, Section 3.4.

#### 4.2.2.3 Home environment

Access to sedentary devices was assessed through children responding to three separate survey questions asking whether they had access in their bedroom to (1) a television, (2) a computer, (3) a games console (yes/no responses) (Ommundsen et al. 2008). Responses were summed (range 0–3) with higher scores representing greater bedroom media availability. Sedentary behaviour restriction was assessed through parents reporting how frequently they restricted their children from viewing TV, playing computer games, and using a computer or tablet. Five response options were available: never (1), rarely (2), sometimes (3), often (4), very often (5), and a composite score was generated using the sum of the three items (range 3–15) (Salmon, Telford & Crawford, 2004). To assess independent mobility, parents reported how frequently their child was allowed to play outdoors anywhere within the neighbourhood, walk or cycle to friends' houses, and play outdoors after dark. Response options were: never (1), rarely (2), sometimes (3), often (4), very often (5), and a composite score was generated using the sum of the three items (range 3–15) (Salmon, Telford & Crawford, 2004). Parents reported whether children had access to a garden or backyard at home (yes/no responses).

#### 4.2.2.4 Neighbourhood environment

The Neighbourhood Environment Walkability Scale for Youth (NEWS-Y) (Rosenberg et al. 2009) was used to assess parental perceptions of neighbourhood design features that may support young people's active neighbourhood recreation and transportation. The 67-item instrument has demonstrated acceptable to good test–retest reliability (ICC=0.56–0.87) (Rosenberg et al. 2009) and has been used previously in child PA research (Kneeshaw-Price et al. 2013) The NEWS-Y is organised into nine subscales representing land-use mix-diversity, neighbourhood recreation facilities, residential density, land-use mix-access, street connectivity, walking/cycling facilities, neighbourhood aesthetics, pedestrian and road traffic safety, and crime safety. Items were averaged with higher scores denoting higher walkability. Higher neighbourhood scores indicated a more walkable environment for all items except pedestrian and road traffic safety, and crime safety items, where higher scores indicated lower walkability (Rosenberg et al. 2009). An overall neighbourhood environment score was also generated from the sum of z-scores for each of the nine.

### 4.2.3 Analyses

Survey packs were initially checked for missing responses then scored following validated procedures for each survey. Where participants had less than one-third of missing responses to a composite variable, these were imputed with the variable mean score ($n$ = 7), and where there was more than one-third of missing responses to a composite variable, these were coded as missing. This imputation approach has been used before in previous PA studies involving children (Corder et al. 2010). Dependent variables were health-related variables (PAQ-C, CRF, BMI z-scores, waist circumference), home environment variables: (garden access, independent mobility, screen-based media restrictions, bedroom media) and NEWS-Y scores (neighbourhood walkability). The independent variable was IMD group. Preliminary analyses highlighted that there were no interactions between IMD groups and gender and so girls and boys were grouped together for the main analyses. To analyse study aim 1, analysis of covariance (ANCOVA) tests assessed IMD group differences in health-related variables, adjusted for CRF (BMI z-score and waist circumference analysis), BMI z-score (CRF analysis) and somatic maturation (PAQ-C analysis); $\chi^2$ with OR as a measure of effect examined IMD group differences in garden/backyard access. Multivariate ANCOVA (MANCOVA) assessed IMD group differences in home and neighbourhood environment variables, adjusted for age. Cohen's d values were calculated as a measure of effect size for ANCOVA, MANCOVA and $\chi^2$ tests. To address study aim 2, and test for differences in relationships between the IMD groups, linear regression analyses stratified by IMD group examined associations between home and neighbourhood environments and health-related variables (BMI z-score, waist circumference, fitness, PAQ-C). Independent mobility was also used as a dependent variable in a further linear regression model to explore its associations with the neighbourhood environment. For both linear regression analyses, simple associations were first explored using correlations, and significant predictor variables were retained and entered into the final models guided by a socio-ecological framework of active living (Sallis et al. 2006). All analyses were conducted using SPSS V.20 (SPSS Inc, Chicago, Illinois, USA).

### 4.3 Results

Of the 217 children who returned written parental informed consent and participant assent, 6 children were not present on the day of testing, and a further 17 children had incomplete data, due to either partially completed questionnaire items or not taking part in anthropometric and/or fitness assessments. Thus, results were available from 194 children (107 girls) (35.3% response rate), of which 169 children (87 girls) (30.8% of the original sample) had complete data. The descriptive characteristics of the participants are presented in Table 4.1. There were no significant differences between children included in analyses and those excluded.

Table 4.1 Characteristics of the study population (*n* = 194)

| Variable | High-deprivation Mean (± SD) or % | | | Medium-to-high deprivation Mean (± SD) or % | | |
|---|---|---|---|---|---|---|
| | All (*n* = 98) | Boys (*n* = 42) | Girls (*n* = 56) | All (*n* = 96) | Boys (*n* = 45) | Girls (*n* = 51) |
| Age (y) | 10.0 (0.3) | 10.0 (0.3) | 10.0 (0.3) | 9.9 (0.3) | 9.9 (0.28) | 9.9 (0.3) |
| Stature (cm) | 140.0 (7.4) | 142.2 (6.2) | 138.4 (7.8) | 138.2 (7.2) | 138.8 (7.3) | 137.7 (7.0) |
| Body mass (kg) | 36.7 (9.1) | 38.5 (8.2) | 35.3 (9.5) | 33.3 (7.4) | 33.0 (6.1) | 33.6 (8.5) |
| Body mass index ($kg\cdot m^2$) | 18.5 (3.5) | 19.0 (3.4) | 18.2 (3.5) | 17.3 (2.8) | 17.0 (1.9) | 17.5 (3.3) |
| BMI z-score | 0.5 (1.3) | 0.8 (1.3) | 0.3 (1.3) | 0.1 (1.2) | 0.2 (0.9) | 0.0 (1.4) |
| Weight status | | | | | | |
| Overweight/obese (%) | 33.7 | 35.7 | 32.1 | 15.6 | 6.7 | 23.5 |
| Waist Circumference (cm) | 65.1 (8.4) | 67.8 (8.6) | 63.0 (7.8) | 62.6 (6.7) | 61.6 (6.1) | 63.5 (7.2) |
| Maturity offset (y) | -2.5 (0.9) | -3.4 (0.4) | -1.9 (0.6) | -2.7 (0.9) | -3.6 (0.4) | -2.0 (0.5) |
| Deprivation score | 51.3 (12.9) | 53.8 (13.1) | 49.4 (12.6) | 22.0 (8.2) | 21.1 (8.3) | 22.8 (8.1) |
| CRF | 35.1 (18.7) | 44.0 (20.4) | 28.5 (14.3) | 41.3 (19.6) | 52.4 (19.1) | 31.5 (14.1) |
| PAQ - C | 3.5 (0.7) | 3.5 (0.7) | 3.4 (0.7) | 3.5 (0.7) | 3.7 (0.7) | 3.3 (0.7) |
| Bedroom media | 1.4 (1.0) | 1.3 (1.1) | 1.5 (1.0) | 1.8 (1.0) | 1.6 (1.1) | 1.8 (1.0) |
| Sedentary behaviour restriction | 9.3 (2.8) | 9.4 (3.3) | 9.3 (2.3) | 9.6 (2.0) | 9.5 (2.3) | 9.6 (1.7) |

| | | | | | | |
|---|---|---|---|---|---|---|
| Independent mobility | 7.2 (2.8) | 7.2 (2.6) | 7.2 (2.9) | 6.2 (2.6) | 6.3 (2.8) | 6.1 (2.5) |
| Land-use mix – diversity | 3.0 (0.7) | 3.0 (0.7) | 3.0 (0.7) | 3.0 (0.7) | 3.1 (0.7) | 2.9 (0.7) |
| Recreation facilities | 2.4 (0.6) | 2.5 (0.6) | 2.3 (0.6) | 2.4 (0.5) | 2.4 (0.5) | 2.4 (0.5) |
| Residential density | 83.1 (25.4) | 85.9 (27.7) | 80.8 (23.3) | 96.2 (21.8) | 94.3 (23.0) | 97.8 (20.9) |
| Land-use mix – access | 3.1 (0.5) | 3.1 (0.5) | 3.2 (0.5) | 3.3 (0.4) | 3.3 (0.4) | 3.2 (0.4) |
| Street connectivity | 2.9 (0.7) | 2.9 (0.7) | 2.9 (0.7) | 2.9 (0.5) | 3.0 (0.6) | 2.8 (0.5) |
| Walking/cycling facilities | 2.9 (0.5) | 2.9 (0.6) | 3.0 (0.5) | 3.0 (0.5) | 3.1 (0.5) | 3.0 (0.6) |
| Neighbourhood aesthetics | 2.1 (0.8) | 2.0 (0.7) | 2.1 (0.8) | 2.9 (0.6) | 2.9 (0.6) | 3.0 (0.6) |
| Pedestrian and road traffic safety | 2.7 (0.4) | 2.6 (0.5) | 2.7 (0.4) | 2.5 (0.4) | 2.4 (0.4) | 2.5 (0.4) |
| Crime safety | 3.0 (0.7) | 2.8 (0.8) | 3.1 (0.6) | 2.6 (0.6) | 2.6 (0.5) | 2.6 (0.6) |
| Walkability Score | -0.1 (3.4) | -0.3 (3.7) | 0.1 (3.1) | 0.2 (3.0) | 0.4 (2.7) | -0.0 (3.2) |

Note. *n*, number of participants BMI, body mass index; IMD, indices of multiple deprivation; CRF, cardiorespiratory fitness; PAQ-C, physical activity questionnaire.

### 4.3.1 Objective 1

There were significant differences between high-deprivation and medium-to-high deprivation children's BMI z-scores ($p < 0.01$, $d = 0.3$), waist circumference ($p < 0.001$, $d = 0.3$) and CRF ($p < 0.01$, $d = 0.3$; Table 4.2).

Table 4.2 Adjusted means of health-related variables by deprivation group

| Variable | High-deprivation mean (95% CI) (*n* = 98) | Medium-to-high deprivation mean (95% CI) (*n* = 96) | *p* value | *d* |
|---|---|---|---|---|
| BMI z-score | 0.5 (0.3 to 0.7) | 0.1 (-0.1 to 0.4) | **0.002** | 0.4 |
| Waist circumference | 64.7 (63.3 to 66.2) | 62.9 (61.4 to 64.4) | **<0.001** | 0.3 |
| CRF | 35.9 (32.1 to 39.7) | 40.5 (36.7 to 44.3) | **0.002** | 0.3 |
| PAQ-C | 3.5 (3.3 to 3.6) | 3.5 (3.3 to 3.6) | 0.22 | 0.0 |

Note. CI, confidence interval; *d*, effect size; *n*, number of participants; BMI, body mass index; CRF, cardiorespiratory fitness; PAQ-C, physical activity questionnaire. Analyses adjusted for CRF (BMI z-score and waist circumference analysis), BMI z-score (CRF analysis) and somatic maturation (PAQ-C analysis).

With regard to home environment variables, high-deprivation children had significantly higher bedroom media availability ($p < 0.05$, $d = 0.4$) and independent mobility scores than medium-to-high deprivation children ($p < 0.05$, $d = 0.4$). The odds of medium-to-high deprivation children having garden or backyard access were greater than the odds of high-deprivation children having it (OR = 4.9; 95% CI 2.3 to 10.4 $p < 0.001$, $d = 0.7$; Table 4.3).

Table 4.3 Adjusted means of home environment variables by deprivation group

| | High-deprivation mean (95% CI) or % (*n* = 88) | Medium-to-high deprivation mean (95% CI) or % (*n* = 88) | *p* value | *d* |
|---|---|---|---|---|
| Garden/backyard | 40.2% | 59.8% | | |
| | OR = 4.9 (2.3 to 10.4) | | <**0.001** | 0.7 |
| Sedentary behaviour restriction | 9.3 (8.8 to 9.9) | 9.6 (9.1 to 10.1) | 0.55 | 0.1 |
| Bedroom media | 1.7 (1.4 to 1.9) | 1.3 (1.0 to 1.5) | **0.01** | 0.4 |
| Independent mobility | 7.2 (6.6 to 7.8) | 6.2 (5.7 to 6.8) | **0.02** | 0.4 |

Note. CI, confidence interval; *d*, effect size; *n*, number of participants; OR, odds ratio. Analyses adjusted for age.

Medium-to-high deprivation children had significantly higher residential density ($p < 0.01$, $d = 0.6$) and neighbourhood aesthetics scores ($p < 0.001$, $d = 1.3$), and lower crime safety ($p < 0.001$, $d = 0.7$) and pedestrian and road traffic safety scores ($p = 0.001$, $d = 0.5$) than high-deprivation children, all of which indicated higher walkability (Table 4.4).

Table 4.4 Adjusted means of neighbourhood environment variables by deprivation group

| Variable | High-deprivation mean (95% CI) (*n* = 82) | Medium-to-high deprivation mean (95% CI) (*n* = 87) | *p* value | *d* |
|---|---|---|---|---|
| Land-use mix–diversity | 3.0 (2.8 to 3.1) | 3.0 (2.9 to 3.1) | 0.96 | 0.0 |
| Recreation facilities | 2.4 (2.2 to 2.5) | 2.4 (2.3 to 2.5) | 0.76 | 0.1 |
| Residential density | 82.0 (77.0 to 87.1) | 96.5 (91.5 to 101.4) | **<0.001** | 0.6 |
| Land-use mix–access | 3.2 (3.1 to 3.3) | 3.2 (3.2 to 3.3) | 0.22 | 0.2 |
| Street connectivity | 2.9 (2.8 to 3.0) | 2.9 (2.8 to 3.1) | 0.87 | 0.0 |
| Walking/cycling facilities | 2.9 (2.8 to 3.1) | 3.0 (2.9 to 3.1) | 0.31 | 0.2 |
| Neighbourhood aesthetics | 2.0 (1.9 to 2.2) | 2.9 (2.8 to 3.1) | **<0.001** | 1.3 |
| Pedestrian and road traffic safety | 2.7 (2.6 to 2.8) | 2.4 (2.4 to 2.5) | **0.001** | 0.5 |
| Crime safety | 3.0 (2.9 to 3.1) | 2.6 (2.5 to 2.7) | **<0.001** | 0.7 |
| NEWS-Y score | -0.1 (-0.8 to 0.6) | 0.6 (-0.5 to 0.8) | 0.59 | 0.1 |

Note. CI, confidence interval; *d*, effect size; *n*, number of participants; NEWS-Y, neighbourhood environment walkability scale. Analyses adjusted for age.

### 4.3.2 Objective 2

Linear regression analysis of the health-related variables demonstrated a significant inverse association between neighbourhood aesthetics and high-deprivation children's BMI z-scores ($\beta = -0.3$, $p < 0.01$), and waist circumferences ($\beta = -0.3$, $p < 0.01$; Table 4.5). High-deprivation children's PAQ-C scores were negatively associated with bedroom media ($\beta = -0.2$, $p < 0.01$), and medium-to-high deprivation children's PAQ-C scores were positively associated with independent mobility ($\beta = 0.3$, $p < 0.01$). Medium-to-high deprivation children's independent mobility was inversely associated with crime safety ($\beta = -0.3$, $p < 0.01$) and neighbourhood aesthetics ($\beta = -0.2$, $p < 0.05$).

Table 4.5 Multiple regression analyses of health and neighbourhood related variables by deprivation group

| Variable | Predictor | High-deprivation | | | Medium-to-high deprivation | | |
|---|---|---|---|---|---|---|---|
| | | B (95% CI) | SE | β | B (95% CI) | SE | β |
| BMI z-score | | | | | | | |
| | Constant | 1.5 (0.7 to 2.3) | 0.4 | - | 0.7 (0.1 to 1.5) | 0.6 | - |
| | Neighbourhood aesthetics | -0.5 (-0.9 to -0.2)** | 0.2 | -0.3 | -0.2 (-0.6 to 0.2) | 0.2 | -0.1 |
| Waist circumference | | | | | | | |
| | Constant | 71.6 (66.7 to 76.6) | 2.5 | - | 62.8 (56.2 to 69.5) | 3.3 | - |
| | Neighbourhood aesthetics | -3.1 (-5.4 to -0.8)** | 1.2 | -0.3 | -0.0 (-2.2 to 2.2) | 1.1 | -0.0 |
| PAQ-C | | | | | | | |
| | Constant | 3.8 (3.2 to 4.3) | 0.3 | - | 3.2 (2.7 to 3.7) | 0.2 | - |
| | Bedroom media | -0.2 (-0.3 to -0.0)** | 0.1 | -0.2 | -0.1 (-0.3 to 0.0) | 0.1 | -0.2 |
| | Independent mobility | 0.0 (-0.0 to 0.1) | 0.0 | 0.1 | 0.1 (0.0 to 0.1)** | 0.0 | 0.3 |
| Independent mobility | | | | | | | |
| | Constant | 9.9 (6.8 to 12.9) | 1.5 | - | 12.6 (8.8 to 16.4) | 1.9 | - |
| | Neighbourhood aesthetics | -0.4 (-1.1 to 0.4) | 0.4 | -0.1 | -1.0 (-1.8 to -0.1)** | 0.4 | -0.2 |
| | Crime safety | -0.6 (-1.4 to 0.2) | 0.4 | -0.2 | -1.4 (-2.3 to -0.4)** | 0.5 | -0.3 |

Note. B, unstandardised beta coefficient; CI, confidence interval; SE, standard error; β, standardised beta coefficient; BMI, body mass index; PAQ-C, physical activity questionnaire; *$p \le .05$; **$p \le .0.1$; ***$p \le .001$.

## 4.4 Discussion

This study aimed (1) to investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation and (2) to assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group. Results indicated differences in health-related variables between children living in high-deprivation and medium-to-high deprivation areas. Moreover, parents' perceptions of neighbourhood walkability were associated with high-deprivation children's BMI and waist circumference, and medium-to-high deprivation children's independent mobility.

Higher waist circumference and overweight prevalence rates were observed among the high-deprivation children compared with their medium-to-high deprivation peers, which is consistent with previous research (Veugelers et al. 2008). If compared with children living in areas of low deprivation, these differences may have been more pronounced (Shrewsbury & Wardle, 2008) given that the majority of children in the present study lived in highly deprived areas. It is suggested that these differences in body weight are significantly influenced by lower socioeconomic conditions that are typically prevalent in high-deprivation areas (Davison & Lawson 2006). Limited access to adequate parks, playgrounds and recreational facilities in highly deprived areas may reduce opportunities for PA and consequently increase the risk of higher weight status (Veugelers & Fitzgerald, 2005). However, as no significant differences were found in PA or perceived recreational provision between high-deprivation children and medium-to-high deprivation children, these differences in waist circumference and weight status may also be related to other factors not examined in this study such as dietary intake (Public Health England, 2013; Cohen et al. 2010) The combined effect of PA and dietary behaviour on weight status though is highly complex and not well understood (Leech et al. 2014). Indeed, healthy behaviours (i.e., regular PA) may compensate for unhealthy ones (i.e., poor diet) which would offer some explanation for the inconsistency across studies. Further research examining the concurrent effect of PA and diet on weight status by deprivation is warranted.

Neighbourhood aesthetics were inversely associated with waist circumference and BMI z-scores. Parents of children living in less aesthetically pleasing neighbourhoods (i.e., limited green spaces, high volumes of street litter and graffiti) are likely to perceive the neighbourhood environment as an unsafe area for their child to be alone in, and in turn, place greater restrictions on their outdoor PA (Tappe et al. 2013) which may lead to increased sedentary time indoors, and reduced EE. Grafova (2008) used interviewer observation to investigate associations between neighbourhood aesthetics and overweight status in children. The study found that children living in neighbourhoods with greater physical disorder in terms of litter and building upkeep were more likely to have a higher BMI than children living in more aesthetically pleasing neighbourhoods. Conversely, Evenson et al. (2007) found no relationship between US girls' BMI and perceptions of their neighbourhood as aesthetically pleasing. These results were based on adolescent girls' perceptions rather than parents', and weight status was assessed using BMI rather than waist circumference and BMI z-score. This heterogeneity in methods and definitions used to assess environmental perceptions and weight status between studies is a key reason for such inconsistencies throughout the literature (Carter & Dubois, 2010; Griffiths et al. 2012).

While favourable aesthetics (e.g., less noise and well maintained recreational areas) may improve children's enjoyment and satisfaction of outdoor neighbourhood play and, in turn, contribute to enhanced PA levels, the present study found no association between neighbourhood aesthetics and children's self-reported PA, and thus, concurs with previous studies (Aarts et al. 2010; Limstrand, 2008). Children residing in less aesthetically pleasing neighbourhoods may simply become used to its aesthetic features, and so will not be discouraged from engaging in PA there (Laxer & Janssen, 2013). Recent US and European studies have reported both positive (Tappe et al. 2013) and negative (De Meester et al. 2014) associations between neighbourhood aesthetics and objectively measured child PA. Associations are known to differ between study area and also between objective and self-report PA measures (Kavanaugh et al. 2014; Reimers et al. 2013). The findings further demonstrate the inconsistent effect of neighbourhood aesthetics on children's PA, and reinforce the need for further research using standardised methodologies. In particular, adopting standardised environmental measures in future research will improve study comparisons and build evidence for environmental investment and policy change (Ding et al. 2011).

In agreement with recent longitudinal research (Crawford et al. 2010; Remmers et al. 2014a), home environmental factors (i.e., independent mobility and media equipment availability) were more strongly associated with both high-deprivation and medium-to-high deprivation children's PA relative to neighbourhood environmental factors, though associations differed between IMD groups. The findings of this study suggest that home environmental factors are potentially more important targets than features of the built environment for future interventions aimed at increasing PA levels in UK children. The present study found no significant associations between neighbourhood environment and children's PA, which is consistent with the findings of others (Davison & Lawson, 2006). Evidence supporting the influence of environmental factors, particularly walkability and crime-related safety, is variable due to non-standardised definitions of environmental factors and disparities in findings between countries which is a key issue for neighbourhood environments research (Aarts et al. 2010; Oliveira et al. 2014).

For high-deprivation children, greater bedroom media availability was associated with less self-reported PA. This finding supports a recent study where increased access to bedroom screen-media equipment was associated with less objectively assessed LPA and MVPA (O'Connor et al. 2013). Together, these findings indicate that the home media equipment environment may have potent negative behavioural effects, especially for high-deprivation children, by providing a greater opportunity to engage in sedentary pursuits (Sirard et al. 2010). Moreover, it may well increase children's exposure to unhealthy food marketing which is associated with higher unhealthy food intake and BMI (Boyland et al. 2011; Halford, 2008), although dietary factors were not within the scope of this study. Consistent with previous findings, children living in areas of high-deprivation had greater access to bedroom media equipment compared with children living in medium-to-high deprivation areas (Kimbro, Brooks-Gunn & McLanahan, 2011). This apparent paradox between high-deprivation and high access to relatively expensive media equipment among Liverpool children has been reported previously (Fairclough et al. 2009). Screen-based activities may be appealing to high-deprivation children who have less opportunity to participate in more expensive leisure activities (Hardy et al. 2010). Conversely, high-deprivation children's parents in this study reported greater concerns about neighbourhood safety (i.e., greater fear of crime and road traffic safety) relative to medium-to-high deprivation children's parents. Thus, it is possible that the high-deprivation children were afforded relatively greater access to media devices to keep them occupied indoors, which was perceived as a safe environment (Burdette & Whitaker, 2005a).

Medium-to-high deprivation children who experienced fewer restrictions on their outdoor play and independent mobility reported higher levels of PA in comparison with medium-to-high deprivation children who experienced greater restrictions on their outdoor play. This finding is consistent with positive associations reported previously between independent mobility and PA in Canada (Stone et al. 2014), Australia (Schoeppe et al. 2014; D'Haese et al. 2013) and the UK (Page et al. 2010). Children with higher levels of independent mobility are likely to play outside and travel actively around the neighbourhood with friends frequently compared with children who face restrictions on their outdoor play and are driven to school, friends' houses, or structured activities (Carver et al. 2014; Fyhri et al. 2011). Stone et al. (2014) found that children who were granted at least some independent mobility had more positive PA profiles across the school week, over the weekend, and during the after-school period than children who faced independent mobility restrictions.

High-deprivation children reported higher levels of independent mobility relative to medium-to-high deprivation children. Despite parents of high-deprivation children reporting less favourable walking environments, their children had fewer restrictions placed on their outdoor play. These counter-intuitive findings concur with previous research reporting greater outdoor play prevalence among high-deprivation children relative to medium-to-high deprivation children (Mitra et al. 2014; Veitch, Salmon & Ball, 2008). Parental neighbourhood safety concerns are less likely to affect the independent mobility levels of UK children living in high-deprivation neighbourhoods, as these children are less likely to be sports club members, due to financial costs of membership (Wijtzes et al. 2014), and may also have no garden or backyard to play in (Public Health England, 2013). In agreement with this view and that of recent research (Chuang et al. 2013), the present study found that medium-to-high deprivation children were 4.88 times more likely to have access to a garden or backyard than high-deprivation children. Furthermore, more deprived residential areas typically have lower street connectivity, which although associated with lower walkability, may also reduce traffic volumes, providing safer places for children to play (Tappe et al. 2013).

Parents of medium-to-high deprivation children were more likely to allow their children to play outdoors if they perceived the neighbourhood as safe, which is consistent with previous studies (Carver, Timperio & Crawford, 2008; Lee et al. 2015; Grafova, 2008; Veitch, Salmon & Ball, 2010). Foster & colleagues (2014) found that parental fear of strangers was inversely associated with children's independent mobility, regardless of whether the social and built environment was supportive of children's PA. A high child presence around the neighbourhood is thought to reduce parental safety concerns and generate an acceptance among parents that it is socially accepted to let children play out in the neighbourhood, resulting in increased independent mobility (Foster et al. 2014; Mackett et al. 2007; Zwerts et al. 2010). Increasing children's independent mobility to play outdoors in the neighbourhood environment with friends, rather than restricting children to the home environment, has the potential to reduce sedentary time (Schaefer et al. 2014) and increase additional time for PA (Atkin et al. 2013; Page et al. 2009; 2010). Further research is warranted to explore the intertwined relationship between parental neighbourhood perceptions, social norms and children's independent mobility.

High-deprivation home environments provided more opportunities for sedentary behaviour and less opportunity for PA. There were, though, fewer parental restrictions placed on high-deprivation children's PA in the neighbourhood environment, despite parents of high-deprivation children reporting less favourable walking environments. Moreover, parental perceptions of the neighbourhood environment related differently to PA outcomes in children of this age, with children living in more aesthetically pleasing and safer neighbourhoods afforded more autonomy over their outdoor play. Neighbourhood environment factors including aesthetics, proximity to recreational facilities, and street design are all particularly difficult factors to alter and to assess their efficacy regarding PA behaviour change (Foster & Hillsdon, 2004). Conversely, home environmental factors such as independent mobility, parental PA encouragement, and sedentary behaviour restrictions are much more modifiable. Facilitating independent mobility and encouraging outside play may serve as an effective strategy to enhance daily PA levels and reduce sedentary time in primary school-aged children (Schoeppe et al. 2013a; 2014), particularly among those not engaged in structured sport participation (Voss et al. 2008). Greater understanding of children's perceptions of the social and built environment, and how these factors influence levels of active play and travel would help with future intervention design. The findings of this study also highlight the importance of understanding parental environmental perceptions given parents' gate-keeping role with respect to children's PA. Future formative research exploring parents' perceptions regarding health-promoting neighbourhoods as well as methods to encourage specific types of parent PA support and independent mobility to promote child PA would be valuable, and could inform future intervention strategies (O'Connor, Jago & Baranowski, 2009; Teedon et al. 2014).

The use of self-reported PA and neighbourhood environment data was a limitation of this study. The PAQ-C though, is a well-established and validated tool which continues to be recommended in youth PA research (Biddle et al. 2011b; Saint-Maurice et al. 2014a; Thomas & Upton, 2014). The survey may have been subject to social desirability biases and its lack of equivalence to time spent in MVPA prohibited discussion of results in relation to public health PA guidelines. The NEWS-Y survey records parental neighbourhood perceptions and as such may also be open to bias from respondents. It is, though, a comprehensive tool to assess the neighbourhood environment, which has previously been shown to have acceptable reliability and to be significantly correlated with PA in youth (Rosenberg et al. 2009). The cross-sectional study design of this study does not allow for causality to be determined, and the findings are generalisable only to children living in areas of medium-to-high deprivation in Liverpool. Deprivation classifications were based on area-level measures which reflect a range of deprivation markers, but may not have accurately reflected the actual deprivation level of all participating families. Moreover, the relatively small sample size and low participant response rate may have biased results, for example, active participants may have been more likely to agree to take part in the study.

Despite these limitations, the findings add to the growing body of literature regarding the effects of the home and neighbourhood environment on children's activity behaviours. Study strengths include the use of a comprehensive socio-ecological conceptual framework to underpin the study, and a collection of validated measures to assess health-related variables and parent environmental perceptions. Moreover, this is the first UK study to explore the influence of neighbourhood characteristics on children's self-reported PA using the NEWS-Y survey. Replication of these methods in other cities may well provide opportunity to generate a UK-wide representation of factors explored in this study. Food intake is also strongly related to anthropometric variables, but was not explored in this study, and should be considered in future studies.

**4.5 Conclusion**

In summary, children living in the most-deprived areas of Liverpool appear to be at greatest risk of unfavourable health-related variables, and are exposed to home and neighbourhood environments that are not conducive to health-promoting behaviours. These findings indicate that children living in highly deprived areas represent an important target group for future interventions designed to promote children's PA. Additional research is warranted to inform future interventions to improve the home and neighbourhood environments of UK children living in deprived residential areas. Home environmental factors were more strongly associated with self-reported PA relative to neighbourhood factors, but the magnitude of these associations varied between deprivation groups. The study demonstrated that having less access to bedroom media equipment and greater independent mobility was strongly associated with higher PA. Facilitating independent mobility and encouraging outdoor play may act as an effective strategy to enhance daily PA levels and reduce sedentary time in children aged 9–10 years. Specific environmental modifications, such as improving neighbourhood aesthetics and crime safety may influence parents in respect of their decisions to grant children autonomy to play in the neighbourhood environment. Parents often perceive a 'trade-off' between ensuring children's safety and fostering their independent mobility (Lorenc et al. 2008). Exploring parents' further views and perceptions towards children's PA and outside play via formative exploratory research may serve as an effective approach to inform the design, recruitment and implementation of future child PA interventions.

**Thesis study map**

| **Study** | **Objectives and key findings** |
|---|---|
| Study 1: Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. | **Objectives:**<br><br>(1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high deprivation and medium-to-high deprivation.<br><br>(2) To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.<br><br>**Key findings:**<br><br>• High deprivation children had higher BMI z-scores and waist circumference and lower CRF compared to medium-to-high deprivation children.<br>• High deprivation children lived in less walkable neighbourhoods and were less likely to have access to a garden than medium-to-high deprivation children.<br>• PA was inversely associated with bedroom media and positively associated with independent mobility.<br>• Independent mobility was inversely associated with crime safety and neighbourhood aesthetics. |
| Study 2. Comparison of children's free-living physical activity derived from wrist and hip raw | **Objectives:**<br><br>(1) To assess children's physical activity levels derived from wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data. |

| | |
|---|---|
| accelerations during the segmented week. | (2) To examine the comparability of physical activity levels between the two devices throughout the segmented week. |
| Study 3. Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity. | |
| Study 4. Parental perceptions on children's out-of-school physical activity and family-based physical activity. | |
| Study 5. Context matters! Sources of variability in weekend physical activity among families: A repeated measures study. | |

# Chapter 5

# Study 2:

# Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week

The main outcomes of this study have been published in the *Journal of Sport Sciences*: Noonan, R. J., Boddy, L. M., Kim, Y., Knowles, Z. R., & Fairclough, S. J. (2016). Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week. *Journal of Sport Sciences*. doi:10.1080/02640414.2016.1255347. The published article can be found in Appendix A.

## 5.1 Introduction

Periods of low PA present an opportune time to promote PA among children. Chapter 4 assessed children's general PA levels but provided limited understanding of PA during specific time periods. Accelerometers provide valid and reliable assessments of PA at varying intensities in children (Butte, Ekelund, & Westerterp, 2012; de Vries et al. 2009), and are the most widely used objective measure of child PA (Cain et al. 2013). One of the advantages of using accelerometers is their ability to capture PA variability within and between days. Accelerometer device output is traditionally expressed as an arbitrary 'count' value which is then related to specific PA intensity thresholds. Due to differences in how raw data are processed, filtered, and scaled, count data cannot be directly compared across studies using different accelerometer devices (Welk, McClain & Ainsworth, 2012). However, the latest versions of accelerometers, including GENEActiv and ActiGraph GT3X+ can provide raw, unfiltered acceleration data. Compared to traditional count-based approaches, raw acceleration data offers greater control over data reduction, potentially allowing comparisons to be made more easily between studies using different accelerometer brands (Fairclough et al. 2016; Hildebrand et al. 2014).

Aside from the challenge of comparing PA levels between device brands, another challenge is the comparability of PA levels between devices placed at different body locations. Traditionally, accelerometers are worn at the hip to capture whole-body movement, but compliance to device wear is typically low (Fairclough et al. 2016). In an attempt to improve device wear there has been an increased use of wrist-worn accelerometers, including the GENEActiv. Compared to hip-worn accelerometers, wrist-worn accelerometers are more sensitive to upper body movement (e.g., climbing, throwing) but less sensitive to sedentary activities (Ellis et al. 2014; Ellis et al. 2016; Kim et al. 2014). This may limit the comparison of findings between studies using wrist and hip-worn accelerometers. Given the increased use of the wrist-worn GENEActiv (da Silva et al. 2014; Edwardson et al. 2015; Keane, et al. 2014; Wake et al. 2014), and the wealth of existing international data obtained from hip-worn ActiGraph accelerometers (Cooper et al. 2015; Corder et al. 2016; Sherar et al. 2011) it is important to understand whether PA estimates derived from wrist-worn GENEActiv (GAwrist) and hip-worn ActiGraph GT3X (AGhip) are comparable.

Fairclough et al. (2016) compared children's whole-day MPA and VPA derived from the GAwrist and AGhip and found that mean PA levels for both intensities were significantly higher for the GAwrist than the AGhip. However, the comparability of PA levels between the GAwrist and AGhip at the lower end of the intensity spectrum is less well understood. Moreover, the agreement between the GAwrist and AGhip may fluctuate in response to variability in PA levels both within and between days (Brooke et al. 2014; Fairclough et al. 2012). However, studies comparing GAwrist and AGhip data have been limited to reporting PA estimates (Fairclough et al. 2016; Rowlands et al. 2014), and raw accelerations across the whole day (Rowlands et al. 2015). Therefore, little is known about their comparability across specific time-segments. For that reason, the aim of this study was to assess children's PA levels derived from GAwrist and AGhip raw acceleration data, and examine the comparability of PA levels between the two devices throughout the segmented week.

## 5.2 Study specific methods

### 5.2.1 Participants and setting

The participants were 129 children (79 girls) aged 9-10 years (age: 10.1 ± 0.3 y (mean ± SD)) from six schools in Liverpool, England. All year 5 children (*n* = 326) in participating schools were invited to participate and received parent and child information sheets, and consent and assent forms, to take home to parents and return upon completion. Written informed consent and assent were received from parents and their children, respectively, before children could participate in the study. Data collection took place between January and May 2014.

### 5.2.2 Measures and procedures

Each child wore a GENEActiv (GAwrist; Activinsights, Cambs, UK) and ActiGraph GT3X+ (AGhip; ActiGraph, Pensacola, FL) accelerometer on their left wrist and right hip, respectively, for seven consecutive days. The GAwrist was selected because it measures raw accelerations, is typically worn on the wrist, and has demonstrated reliability and validity in child populations (Phillips, Parfitt & Rowlands, 2013). ActiGraph accelerometers are the most commonly used accelerometer in child PA research (Cain et al. 2013). The GT3X+ model was selected because it is traditionally worn on the hip (Rosenberger et al. 2013), has the capability to generate raw acceleration data, and has been validated for use with children (Hanggia, Phillips & Rowlands, 2013; Robusto & Trost, 2012). Children were instructed to wear both monitors concurrently during all waking hours except when engaged in water-based activities. Verbal and written instructions for care and placement of the monitors were given to children. Prior to testing, monitors were synchronised with Greenwich Mean Time (GMT) and programmed to record data at 100 Hz. Data collection took place during the regular school term so activities were representative of usual free-living activities.

### 5.2.3 Analyses

GAwrist data were downloaded using GENEActiv v.2.2 software (Activinsights, Cambs, UK) and saved in raw format as binary files. AGhip data were downloaded using ActiLife v. 6.11.4 (ActiGraph, Pensacola, FL) and saved in raw format as GT3X files. These were subsequently converted to CSV format to facilitate raw data processing. GAwrist and AGhip raw data files were then processed in R (http://cran.r-project.org) using the GGIR package (version 1.1-4) which converted raw triaxial acceleration values into one omnidirectional measure of acceleration, termed the signal vector magnitude (SVM). SVM was calculated from raw accelerations from the three axes minus 1*g* which represents the value of gravity (i.e., SVM = √(x2 + y2 + z2) – 1), after which negative values were rounded to zero. This metric is referred to as the Euclidean norm minus one (ENMO) (van Hees et al. 2013). Raw data were further reduced by calculating the average SVM values per 1-s epoch expressed in *mg* over each of the 7 monitored days. Wear time periods for raw data from GAwrist and

AGhip were estimated on the basis of the standard deviation and value range of each axis, calculated for 60 min moving windows with 15 min increments (van Hees et al. 2013). A time window was classified as non-wear time if, for at least 2 out of the 3 axes, the standard deviation was less than 13.0 *mg* or if the value range was less than 50 *mg* (van Hees et al. 2013). A valid day was classified as 10 hours or more of device wear. At a minimum, children were required to have worn both devices on the same 3 days including 1 weekend day to be included in the analyses (Mattocks et al. 2008).

Device specific prediction equations provided by Hildebrand et al. (2014) were used to identify ENMO cut-points for classifying LPA and MVPA (Hildebrand et al. 2014). It has recently been reported that in youth 2 METs and 4 METs had higher classification accuracy for differentiating sedentary time (from LPA) and MVPA (from LPA), respectively, compared with 1.5 METs and 3 METs (Saint-Maurice et al. 2016). Therefore, the Hildebrand equations were solved for 2 METs and 4 METs resulting in LPA and MPVA cut-points of 23.5*mg* and 359.7*mg*, respectively, for GAwrist, and 35.2 *mg* and 249.9 *mg*, respectively, for AGhip. For example, the GAwrist LPA *mg* cut-point threshold was calculated as follows: $mg = ((2\text{METs} \times 6\ \text{mL}\ O_2 \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) – 11.16)/0.0357 = 23.5\ mg$.

Once converted to minutes of LPA and MVPA, data were sorted into hourly segments from 06:30 until 23:59 on weekdays and weekend days using Stata (STATA/SE Version 12; StataCorp LP, College Station, TX). Sleep time was defined as midnight until 06:30. These hourly values were then used to construct whole-day and segmented day minutes of LPA and MVPA. During weekdays the following time segments were used: before-school (06.30 to 08:59), during-school (09:00 to 15:29), and after-school (15:30 to 23:59). For weekend days the segments were: morning (06:30 to 11:59) and afternoon-evening (12:00 to 23:59). Variables were calculated by summing minutes spent in each activity threshold during each discrete time segment. To account for differences in segment length, mean minutes of GAwrist and AGhip LPA and MVPA for each segment, were divided by total segment time, multiplied by 100 and expressed as percentage of total segment time.

The primary outcome variables were percentage segment time for LPA and MVPA. Repeated measures ANOVAs examined between segment differences for each device (e.g., GAwrist LPA whole weekday vs GAwrist LPA whole weekend day), and between device differences for each segment (e.g., GAwrist LPA whole weekday vs AGhip LPA whole weekend day). Pearson correlation analyses examined associations between the two devices for percentage of time spent in LPA and MVPA during whole-day weekday and weekend day. Bland–Altman plots were constructed to assess between-device agreement of LPA and MVPA for whole weekday and whole weekend day segments. All analyses were conducted using IBM SPSS Statistics v.23 (IBM, Armonk, NY) and Microsoft Excel 2010 (Microsoft, Redmond, WA). For all analyses, statistical significance was set at $p \leq 0.05$.

## 5.3 Results

AGhip and GAwrist data were available for 115 and 128 children, respectively. Participants not meeting the wear time criteria for either monitor were excluded from analyses. This reduced the sample to 107 (67 girls) for the GAwrist and 83 (51 girls) for the AGhip. Children without 3 valid days for both monitors were then excluded from the analysis, resulting in a final analytical sample of 77 (48 girls) participants. There were no significant differences for any of the measured variables between children included in analyses and those excluded. Means and 95% confidence intervals (CI) for PA outcomes on weekdays and weekend days for GAwrist and AGhip are presented in Table 5.1. Whole weekday PA outcomes were higher than mean whole weekend day PA outcomes ($p < 0.05$). PA outcomes were higher during the school segment compared to all other weekday segments ($p < 0.001$). On weekend days children were more active in the afternoon-evening compared to the morning ($p < 0.01$).

GAwrist PA levels were significantly higher than AGhip PA levels during all weekday and weekend day segments ($p < 0.001$; Table 5.1) but varied between time segments and PA intensities. On weekdays the largest inter-device differences in PA levels occurred during the school segment (LPA 26.7%; MVPA 1.8%; $p < 0.001$), and the smallest inter-device differences occurred in the before-school segment (LPA 10.3%;

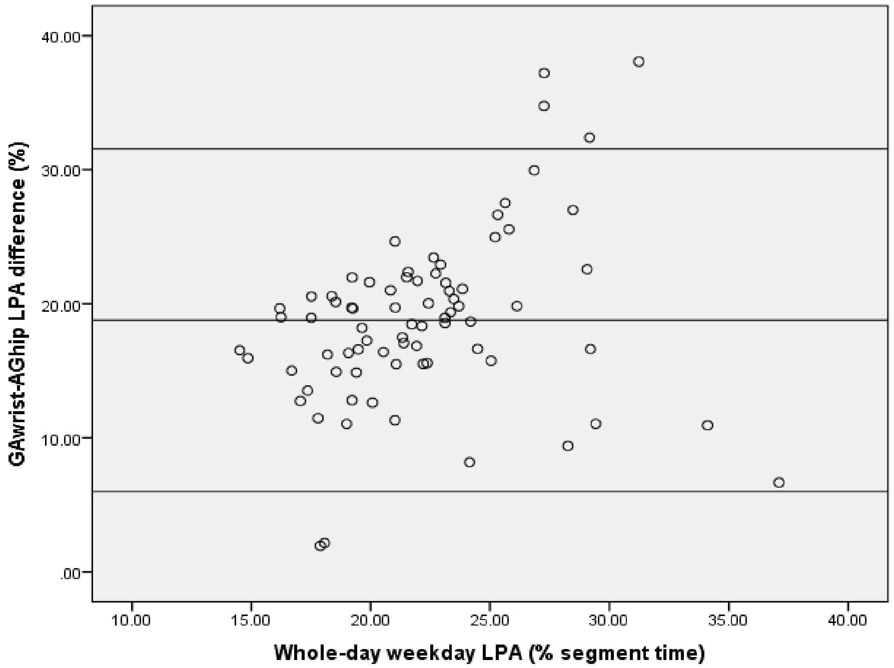
MVPA 0.5%; $p < 0.001$). On weekend days the largest inter-device differences occurred in the afternoon-evening (LPA 17.7%; MVPA 1.6%; $p < 0.001$), and the smallest inter-device differences occurred in the morning (LPA 10.3%, MVPA 0.8%; $p < 0.001$). For all intensities the magnitude of inter-device differences was largest at weekends compared to weekdays.

Significant correlations between whole weekday ($r = 0.8$) and whole weekend day ($r = 0.9$) MVPA levels confirmed that MVPA was strongly associated between devices ($p < 0.001$). Correlations between the devices were weak for LPA during whole weekdays ($r = 0.3$ $p < 0.01$) and whole weekend days ($r = 0.2$; $p = 0.11$). Bland–Altman plots (Figure 5.1a and b) show the extent of differences in LPA and MVPA between GAwrist and AGhip during whole weekdays and weekend days.

Table 5.1 PA outcomes for GAwrist and AGhip for weekday and weekend day segments

| | GAwrist | | | | AGhip | | | | GAwrist - AGhip segment difference |
|---|---|---|---|---|---|---|---|---|---|
| | Mean minutes | 95% CI | % segment time | 95% CI | Mean minutes | 95% CI | % segment time | 95% CI | % |
| LPA | | | | | | | | | |
| Whole week | 306.8 | 291.3 - 322.3 | 29.2 | 27.9 - 30.9 | 128.8 | 118.3 - 139.5 | 12.3 | 11.3 - 13.4 | 16.9*** |
| Whole weekday | 329.9 | 316.6 - 343.3 | 31.5+++ | 30.3 - 33.0 | 134.7 | 124.4 - 145.1 | 12.9+ | 11.8 - 13.9 | 18.6*** |
| Before-school | 34.8 | 31.6 - 38.0 | 23.3 | 21.1 - 25.6 | 18.3 | 16.0 - 20.5 | 12.3 | 10.8 - 13.8 | 11.0*** |
| During-school | 165.5 | 160.1 - 173.0 | 42.6‡‡‡ | 40.6 - 44.5 | 61.7 | 56.4 - 67.4 | 15.9‡‡‡ | 14.6 - 17.3 | 26.7*** |
| After-school | 129.6 | 121.7 - 137.5 | 25.5 | 23.7 - 27.2 | 54.7 | 49.3 - 60.1 | 10.8 | 9.8 - 11.9 | 14.7*** |
| Whole weekend day | 283.6 | 265.9 - 301.3 | 27.1 | 25.4 - 28.8 | 122.9 | 112.1 - 133.8 | 11.7 | 10.7 - 12.8 | 15.4*** |
| Morning | 58.3 | 48.4 - 68.1 | 17.7 | 14.7 - 20.7 | 24.5 | 20.5 - 28.6 | 7.4 | 6.2 - 8.7 | 10.3*** |
| Afternoon-evening | 225.4 | 213.0 - 37.8 | 31.4††† | 29.6 - 33.1 | 98.3 | 88.5 - 108.2 | 13.7††† | 12.3 - 15.1 | 17.7*** |
| MVPA | | | | | | | | | |
| Whole week | 30.0 | 27.3 - 32.8 | 2.9 | 2.6 - 3.2 | 16.5 | 14.5 - 18.5 | 1.6 | 1.4 - 1.8 | 1.3*** |
| Whole weekday | 31.9 | 29.7 - 34.2 | 3.0+ | 2.8 - 3.3 | 18.7 | 17.2 - 20.2 | 1.8+++ | 1.7 - 2.0 | 1.2*** |
| Before-school | 2.4 | 2.0 - 2.8 | 1.6 | 1.4 - 1.9 | 1.7 | 1.4 - 2.0 | 1.1 | 0.9 - 1.3 | 0.5*** |
| During-school | 16.7 | 15.3 - 18.0 | 4.3‡‡‡ | 3.9 - 4.7 | 9.8 | 8.8 - 10.7 | 2.5‡‡‡ | 2.2 - 2.7 | 1.8*** |
| After-school | 12.7 | 11.4 - 14.1 | 2.5 | 2.2 - 2.8 | 7.2 | 6.2 - 8.3 | 1.4 | 1.2 - 1.6 | 1.1*** |
| Whole weekend day | 28.1 | 24.8 - 31.4 | 2.7 | 2.3 - 3.0 | 14.2 | 11.8 - 16.7 | 1.4 | 1.1 - 1.6 | 1.3*** |
| Morning | 5.9 | 4.1 - 7.6 | 1.8 | 1.3 - 2.3 | 3.3 | 2.2 - 4.5 | 1.0 | 0.7 - 1.4 | 0.8*** |
| Afternoon-evening | 22.2 | 19.1 - 25.2 | 3.1††† | 2.7 - 3.5 | 10.9 | 8.8 - 12.9 | 1.5†† | 1.2 - 1.8 | 1.6*** |

Significantly different between GAwrist % segment and AGhip % segment at $***p < 0.001$. Significantly different between GAwrist % weekday and % weekend day at $+p < 0.05$, $+++p < 0.001$. Significantly different between AGhip % weekday and % weekend day at $+p < 0.05$, $+++p < 0.001$. Significantly different between GAwrist % before-school – % during-school – % after-school at ‡‡‡$p < 0.001$. Significantly different between AGhip % before-school – % during-school – % after-school at ‡‡‡$p < 0.001$. Significantly different between GAwrist % weekend morning and % afternoon-evening at †††$p < 0.001$. Significantly different between AGhip % weekend morning and % afternoon-evening at ††$p < 0.01$, †††$p < 0.001$.



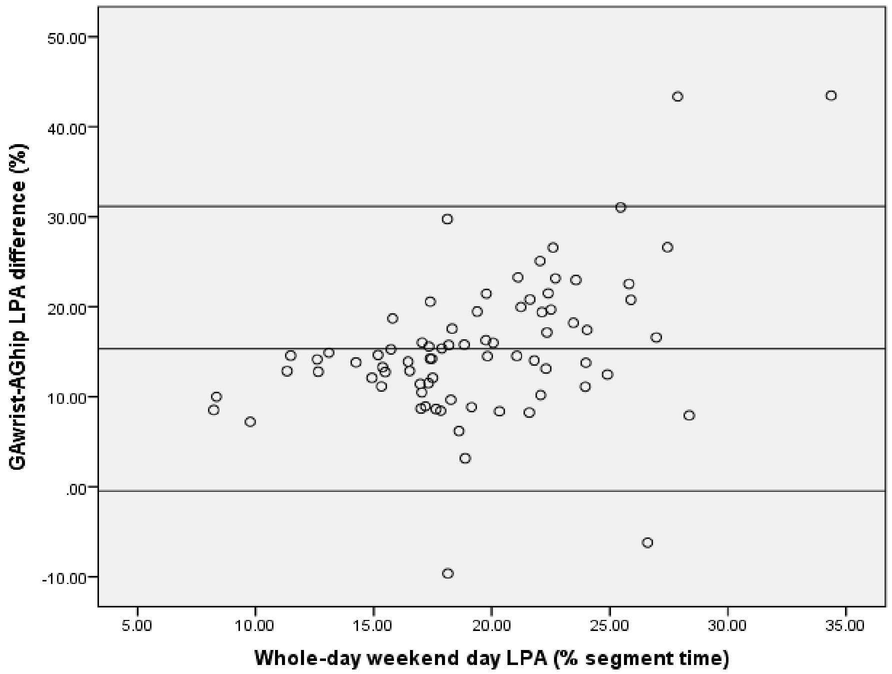




Figure 5.1a Bland–Altman plots displaying agreement between GAwrist and AGhip derived whole weekday and whole weekend day LPA. Note that the observed positive bias indicates that GAwrist values were higher than AGhip values. Horizontal lines represent mean bias and 95% limits of agreement.

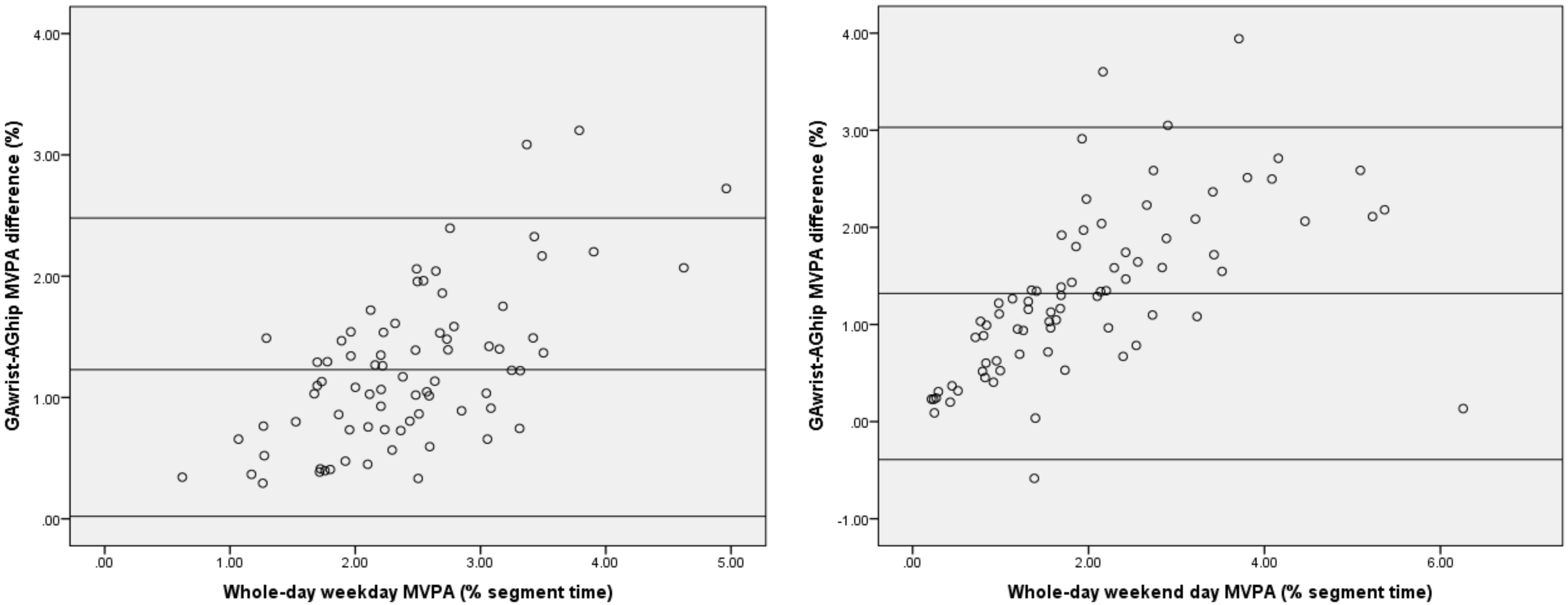



Figure 5.1b Bland–Altman plots displaying agreement between GAwrist and AGhip derived whole weekday and whole weekend day MVPA. Note that the observed positive bias indicates that GAwrist values were higher than AGhip values. Horizontal lines represent mean bias and 95% limits of agreement.

## 5.4 Discussion

This is the first study to compare children's LPA and MVPA assessed with GAwrist and AGhip across distinct time windows in a week. Another novel aspect of this study is the use of raw data processing techniques, which theoretically enables direct comparisons of activity outcomes obtained from different accelerometer brands. Overall, the study found weak correlations between AGhip and GAwrist for LPA ($r$ = 0.2 - 0.3), but strong correlations for MVPA ($r$ = 0.8 - 0.9). The strong correlations observed for MVPA are similar to those reported by Fairclough et al. (2016). They are though slightly lower than the reported correlation of $r$ = 0.93 between hip-worn GENEActiv and ActiGraph GT3X+ mean accelerations (Rowlands et al. 2015). Despite these strong associations, the study found that GAwrist derived PA levels were consistently higher than those derived from the AGhip for all outcome variables and across various time segments. These findings suggest that child PA surveillance is strongly influenced by device brand and body placement.

LPA and MVPA levels during all weekday and weekend day segments were significantly higher for the GAwrist than those for the AGhip ($p < 0.001$). Previous research comparing whole-day accelerometer output from wrist-worn GENEActiv and hip-worn ActiGraph in children reported similar findings (Fairclough et al. 2016; Hildebrand et al. 2014). Fairclough et al. (2016) reported a 68% difference in the number of children achieving at least 60 minutes of MVPA per day using the GENEActiv compared to ActiGraph GT3X+. Similarly, Rowlands et al. (2015) found that average daily accelerations from the wrist-worn GENEA were between 12%–13% higher than the ActiGraph GT3X+. Another recent study found that the ActiGraph GT3X+ worn on the wrist produced higher average step counts per day compared to the ActiGraph GT3X+ at the hip in free-living environments, but fewer steps during laboratory treadmill testing (Tudor-Locke, Barreira & Schuna, 2015). These contrasting differences in step outputs between research settings are likely consequential of the restrictive nature of treadmill walking which minimises free swinging of the arms relative to free-living (Pontzer et al. 2009).

A unique element of this study is the comparison of PA levels between GAwrist and AGhip across different time segments. The study found that differences in PA levels between the two devices varied in magnitude between intensity levels. As the intensity level increased, the magnitude of the difference in PA levels between the GAwrist and AGhip decreased. The largest differences in PA levels were seen in LPA. Mean GAwrist LPA was over 100% higher than that for the AGhip in all segments with the exception of the before school segment.

During free-living children typically engage in a range of seated activities that involve a high level of arm movement but limited movement at the hip (Kim et al. 2014). Unsurprisingly, during such activities, disproportionate levels of acceleration will be observed at the wrist relative to the hip. This is reflected by the high inter-device difference in LPA during the school day segment. LPA accounted for 42.6% and 15.6% of school segment time for the GAwrist and AGhip, respectively, a difference of over 26%. The profound difference in LPA observed during the school day likely reflects these disjointed wrist and hip movement patterns when children characteristically spend a large proportion of the day seated at a desk reading, writing, or using a computer which all involve some element of wrist movement. Greater accelerations will also be observed at the wrist relative to the hip during mixed static/dynamic movements (e.g., playing catch), and high intensity activities such as running and jumping that naturally incur a medium to high level of shoulder and upper body rotation (Ellis et al. 2014, 2016; Kim et al. 2014). However, the level of decoupling (i.e., greater acceleration capture at one wear site relative to the other) during such activities is likely dependent on individual biomechanics (i.e., level of arm swing), and thus will be population specific (Rowlands & Stiles, 2012; Tudor-Locke et al. 2015).

The weaker correlations and larger inter-device differences observed for LPA compared to MVPA suggests that in children of this age, pro-wrist "decoupling", is more dominant during LPA. In contrast, earlier studies observed greater decoupling as the magnitude of acceleration increased. However, these studies did not examine accelerations at intensities lower than 3 METs (Fairclough et al. 2016; Hildebrand et al. 2014). Children's free-living accelerations were over 10% greater for the GENEActiv compared to the ActiGraph in a recent study when both devices were worn at the hip (Rowlands et al. 2015). This suggests that additional factors other than monitor placement may have also contributed to the observed differences in GAwrist and AGhip PA levels. Similarly, John, Sasaki and Staudenmayer (2013) found that GENEActiv peak accelerations were up to 7.4% greater than ActiGraph peak accelerations during mechanical shaker testing. Irrespective of placement location, potential factors that may cause inter-monitor differences in raw acceleration between the GAwrist and AGhip include differences in microelectromechanical sensors, dynamic ranges and proprietary filtering processes used to minimise signal distortion during initial analogue-to-digital conversion (John & Freedson 2012; John et al. 2013). Therefore, the current generation of accelerometry-based monitors may not be directly compared with each other even at the raw acceleration level, due to the discrepancies in how the raw data are collected and filtered. Further research and/or discussions are required to achieve the "true" harmonization of raw data collected from different types of devices.

A common outcome in child PA research is time spent in MVPA which is used to identify the number of children meeting the PA guidelines (i.e., at least 60 min of MVPA per day) (Chief Medical Officers, 2011). To complicate comparisons further between GAwrist and AGhip, accelerometer data are commonly analysed using a broad range of intensity thresholds leading to widely varying estimates of MVPA within and between studies (Guinhouya, Samouda & de Beaufort, 2013; Routen et al. 2012). For example, Schaefer, Nace and Browning (2014) found that estimates of wrist derived MVPA decreased by 27% (from 308 to 225 minutes) when the MVPA cut-point threshold was increased from 3 METs to 4 METs. The difference in MVPA levels between GAwrist and AGhip within this study and between other studies highlights the influence of device and wear location on MVPA prevalence, and the challenge of comparing MVPA data between studies using different intensity thresholds and devices worn at different body locations.

Presently, there are few developed equating systems to compare raw accelerations and estimates of MVPA across different devices and wear-sites. Rowlands et al. (2015) found that applying a population specific correction factor to GAwrist data removed the significant difference in accelerations between GAwrist and AGhip data. Rowlands et al. (2016a) developed a method to facilitate the comparison of group level estimates of children's MVPA derived from uniaxial hip-worn count-based ActiGraphs to triaxial raw acceleration data measured using wrist-worn GENEActiv. The study revealed that depending on the data reduction procedure used, comparable estimates of minutes spent in MVPA could be obtained between the wrist and hip. These two methods may therefore be an appropriate way of improving the comparability of raw data between studies using different device brands and placement locations in the future. However, the study did not provide a way to standardise previously published group-level estimates of MVPA so data could be compared across different cut-points or placements. Therefore, further research is warranted to develop conversion equations to compare estimates of MVPA derived from accelerations measured at the wrist and from ActiGraph counts measured at the hip.

This is the first study to examine the comparability of GAwrist and AGhip derived LPA and MVPA throughout the segmented week. The study observed differential agreement between GAwrist and AGhip. Agreement differed according to PA intensity and time of day, with the greatest difference occurring in LPA during school hours. Future studies should therefore be cautious when comparing PA data derived from GAwrist and AGhip, especially studies investigating children's school day PA and segmented days. PA levels were derived from raw acceleration data and were processed and analysed using the same open-source procedures, which adds transparency and consistency to the data. However, the results of this study were performed in a relatively small sample of children living in a highly deprived area of England, which limits the generalisability of findings to other locations and populations. Device wear time was greater for the GAwrist compared to the AGhip which may have contributed to the observed differences in PA levels. The inclusion criteria used in this study for whole-day device wear is consistent with recommendations and common practices, but wear time criteria was not applied to specific time segments (e.g., before-school). This may have biased the PA outcomes for individual segments depending on segment wear time.

### 5.5 Conclusion

In conclusion, PA levels from the GAwrist and AGhip are not comparable under free-living conditions. PA levels derived using raw data processing procedures were significantly higher for GAwrist compared with those for AGhip during all time segments. The magnitude of these differences was greatest during school hours and in LPA. Comparisons of raw data assessed by different monitors worn at the wrist and hip in children should therefore be undertaken with caution. Further research is needed to develop PA level correction factors to aid comparison of findings between studies using the GAwrist and AGhip.

**Thesis study map**

| **Study** | **Objectives and key findings** |
|---|---|
| Study 1: Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. | **Objectives:**<br><br>(1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation.<br><br>(2) To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.<br><br>**Key findings:**<br><br>• High deprivation children had higher BMI z-scores and waist circumference and lower CRF compared to medium-to-high deprivation children.<br>• High deprivation children lived in less walkable neighbourhoods and were less likely to have access to a garden than medium-to-high deprivation children.<br>• PA was inversely associated with bedroom media and positively associated with independent mobility.<br>• Independent mobility was inversely associated with crime safety and neighbourhood aesthetics. |
| Study 2. Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week. | **Objectives:**<br><br>(1) To assess children's physical activity levels derived from wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data. |

<table>
<tr><td></td><td>(2) To examine the comparability of physical activity levels between the two devices throughout the segmented week.<br><br>Key findings:<br><ul><li>Children’s raw PA levels were lowest on weekend days.</li><li>Wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ derived raw PA levels are not comparable in children.</li><li>The largest differences in GAwrist and AGhip derived raw PA were observed at the lowest intensity and during school hours.</li></ul></td></tr>
<tr><td>Study 3. Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity.</td><td>Objectives:<br><br>(1) To use a novel combination of qualitative techniques to explore children’s current views, experiences and perceptions of out-of-school physical activity as well as offering formative opinion about future intervention design.</td></tr>
<tr><td colspan="2">Study 4. Parental perceptions on children’s out-of-school physical activity and family-based physical activity.</td></tr>
<tr><td colspan="2">Study 5. Context matters! Sources of variability in weekend physical activity among families: A repeated measures study.</td></tr>
</table>

# Chapter 6

# Study 3:

# Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity

The main outcomes of this study have been published in *BMC Public Health*: Noonan, R. J., Boddy, L. M., Fairclough, S. J., & Knowles, Z. R. (2016). Write, draw, show, and tell: A child-centred dual methodology to explore perceptions of out-of-school physical activity. *BMC Public Health*, 16:326. The published article can be found in Appendix A.

### 6.1 Introduction

Chapter 5 identified the out-of-school period as a period prone to low MVPA. Eliciting children's perspectives on out-of-school PA is central to understanding their out-of-school PA behaviours (Craig et al. 2008; Davison et al. 2013). Presently, there is a dearth of literature featuring the 'children's voice'. Qualitative research exploring children's PA is largely based upon data generated from parent led focus groups (Eyre et al. 2014; Hesketh et al. 2012) and interviews (O'Connor & Brown, 2013; Zahra, Sebire & Jago, 2015). Moreover, formative child PA intervention research has generally proceeded with the informed view of what parents consider children need rather than adopting a humanistic child-led approach (Bentley et al. 2012; De Lepeleere et al. 2013; Jago et al. 2012).

Humanism is a 'holistic' approach that emphasises the study of the whole child, through the eyes of the child, rather than the eyes of parents or researcher. The approach encourages children to think about their own personal feelings, and how they perceive and interpret experiences thereby offering a unique child-centred insight into the factors that drive children's behaviour (Morse, 2012). Child-led focus groups are humanistic and acknowledge children as experts (Greene & Hogan, 2005). They have been used before to explore children's perspectives and attitudes towards PA (Lassetter et al. 2015; Mackintosh et al. 2011). However, because children differ in cognitive and linguistic ability, interaction preference, and experience similar events in rather different ways, a more developmentally appropriate and creative methodology than focus groups may be needed (Feldman, 2011; Gibson, 2012).

Participatory visual methods such as write and draw and its variations are highly efficient and ethically compliant research methods that are particularly suited for research with children for reasons of inclusivity and interactivity (Angell, Alexander & Hunt, 2015; Literat, 2013). Write and draw is popular in child-focused health research (Horstman et al.

2008; Kostmann & Nilsson, 2012; McWhirter, 2014) and has been used recently to explore children's PA beliefs (Cammisa, Montrone & Caroli, 2011) and playground experiences (Knowles et al. 2013). When compared to other qualitative approaches, drawing provides children with greater control over their expression, allowing them to reflect upon and articulate what is important to them, and the drawings themselves are rich visual illustrations that directly represent children's perspectives and/or experiences (Enright & O'Sullivan, 2012; Gabhainn & Kelleher, 2002). To date, research employing write and draw has somewhat focussed on drawing as representation with an emphasis on the marks made on paper (i.e., drawing alone) or a combination of drawing and labelling as a source of data (Knowles et al. 2013; McWhirter, 2014). Such representations may not, however, be an accurate reflection of children's intended meaning, as the interpretation of the drawing is researcher dependent and may therefore influence study credibility (Cox, 2005; Einarsdottir, Dockett & Perry, 2009).

Write, draw, show and tell (WDST) is a new method that represents an evolution of the write and draw and focus group method. The current study introduces WDST and provides a conceptual framework and practical checklist for its future application (Table 6.1). Contrary to that of traditional write and draw approaches, children are encouraged to articulate their own meaning embedded within their drawing and thus individual narrative commentary is formed (i.e., drawing as meaning-making) (Dockett & Perry, 2005; Angell & Angell, 2013). Aside from providing children with greater control over their expression and recognising the social context in children's drawing (Anning, 2002; Harcourt, 2011), considering both representations together provides a more comprehensive and credible account of children's perceptions and experiences in both an empowering and personally relevant manner (Literat, 2013; Tay-Lim & Lim, 2013). As a whole, the WDST method provides children with alternative ways of expression and enables a deeper exploration of children's thoughts and perceptions by not limiting children to verbal communication. It was envisioned that the interactive and dual methods based approach (i.e., WDST) would foster greater inclusivity and would elicit more representative and detailed perceptions on out-of-school PA that perhaps would remain uncovered when using traditional singular methods based approaches including focus groups (Dockett & Perry, 2005; 2007; Gibson, 2007; Morgan et al. 2007).

Table 6.1 Write, draw, show and tell methodology framework

| | |
|---|---|
| Philosophy | • Humanistic<br>• Children as experts<br>• Unique perspective unnoticed from adult world |
| Recruitment | • Study recruitment information given<br>• Parental consent and child assent obtained |
| Assent | • Verbal explanation of research purpose, processes involved and data uses<br>• Verbal explanation of structure and context of WDST group - write/draw/storytelling etc.<br>• Obtain verbal child assent |
| Setting | • Area where children can be seen but not overheard.<br>• Circular seating arrangement with researcher sat with children.<br>• Researcher and children address each other by first name. |
| Show | • Interactive ice breaker activity.<br>• Provides children opportunity to practice speaking aloud and establishes an environment in which sharing and listening is valued.<br>• Provide post-it note© paper and a pencil to write down responses.<br>• Children place responses on to a flip chart board and before doing so provide a verbal account of the meaning behind written responses. |
| Write & Draw | • Write and draw activity.<br>• Free access to drawing materials/no constraints on contribution or time.<br>• Engage children in child-centred informal conversation to verify interpretation and add context to drawing.<br>• Provide motivational comments but refrain from providing evaluation of drawings. |
| Tell | • Proceed with group discussion around more cognitively challenging open-ended questions.<br>• Use terms and terminology used by children.<br>• Ensure all children have equal opportunity to contribute.<br>• Demonstrate genuine interest in children's perspectives (i.e., paraphrase responses, relate responses to earlier comment or to one made by another child).<br>• Seek clarification (i.e., probe for deeper explanations and real life examples). |
| Analysis | • Triangulate and pool all three data streams<br>• Content analysis of themes<br>• Present visual representation of drawing combined with narrative<br>• Pen profile analysis |

Research to learn more about children's PA behaviours and inform intervention design has, to date, largely underrepresented children's voices (Bentley et al. 2012; De Lepeleere et al. 2013; Jago et al. 2012) and been limited to singular qualitative methods that overlook children's varied linguistic ability and interaction preference (Brockman et al. 2009; Stanley, Boshoff & Dollman, 2012). An exception to this however is a recent Australian study (Maitland et al. 2014) that employed a range of methods including a family interview, home tour and direct observation to explore children's and parents' perceptions of home physical environmental influences on children's PA and sedentary time. Interviews may, however, have been prone to social desirability given that interviews were conducted in the presence of parents (Havermans, Vanassche & Matthijs, 2015; Krumpal, 2013). A more detailed understanding of UK children's perceptions of context specific PA, the participation barriers they face, as well as factors that support them to lead a physically active lifestyle may inform future PA promotion strategies including intervention design aimed at low active UK children. The aim of this study was to therefore use a combination of qualitative techniques to explore children's current views, experiences and perceptions of out–of-school PA as well as offering formative opinion about future intervention design. It is envisaged that the contextual information gathered from this study will a) provide valuable insights into the meanings children ascribe towards PA, and b) inform the design of future out-of-school PA promotion strategies targeting primary school aged children.

## 6.2 Study specific methods

### 6.2.1 Participants and setting

Participants in this study were schoolchildren aged 10–11 years from Liverpool, England. Seven primary schools spanning a range of socioeconomic areas were approached as convenience samples and agreed to participate in the study. Participants were eligible to take part if they had participated in study 1. Following gatekeeper consent, information packs containing child and parent information sheets and consent forms were distributed to all eligible children ($n$ = 181) at schools to take home to parents. For the purpose of this formative study five consenting children from each school were randomly selected via lottery method to take part in a WDST group. Written informed consent and assent were obtained for 63 children (34.8% response rate), and 35 (16 boys) of them took part in the WDST groups. Data were collected throughout October 2014.

### 6.2.2 Measures and procedures

#### 6.2.2.1 Write, draw, show and tell (WDST)

WDST groups were arranged and conducted by the one researcher. Semi-structured WDST group guides were used to ensure consistency across WDST groups, and questions were informed by the YPAPM (Welk, 1999). Example WDST group questions aligned to categories of the YPAPM (Welk, 1999) are presented in Table 6.2. The research team have extensive experience working with children and conducting research on topics similar to that explored in the current study (Mackintosh et al. 2011; Knowles et al. 2013; Boddy et al. 2012; Downs et al. 2013; Porcellato & Knowles, 2014; Ridgers, Knowles & Sayers, 2012). The focus group guides used in the aforementioned studies were used to inform the structure and content of the WDST guide. Prior to data collection the WDST guide was assessed independently by the lead researcher and research team after which a group meeting took place. The WDST guide was discussed among the team and a collective consensus was reached that the phrasing of the WDST questions and activities were age appropriate and would allow for the study aims to be achieved. One question was revised in order to improve clarity. ‘’Can you think of anything that stops you from playing outdoors” was revised to ‘’Can you think of anything that stops you from playing outdoors by your home as opposed to playing indoors?” One member of the research team, an expert in the field as a Chartered Psychologist, provided feedback as regards age appropriateness. Therefore, the questions used demonstrated face validity.

Table 6.2 Example WDST questions

| YPAPM Topic | |
|---|---|
| Predisposing | Predisposing: What sorts of physical activities do you most like taking part in outside of school? Why do you like this activity more than others? |
| Enabling | Enabling: What sorts of things tend to stop you from doing physical activity? |
| Reinforcing | Reinforcing: What sorts of things do your parents or carers do that helps you be more active? |

A range of qualitative techniques referred to here as WDST were incorporated into WDST groups to further stimulate children's thinking and facilitate discussion around PA (Darbyshire, MacDougall & Schiller, 2005; Pearce et al. 2009) (refer to Table 6.1). The WDST group started with less challenging tasks and questions that children could answer as experts such as their favourite physical activities.

An ice breaker task was used at the beginning of each WDST group to provide children the opportunity to experience talking aloud to the group, and to establish an environment in which sharing and listening was valued (Gibson, 2012). Children were provided with post-it note© paper and a pencil and asked to write down '5 words to best describe PA to someone else'. Children subsequently placed their responses on to a flip chart board and before doing so provided a verbal explanation of the meaning behind their written responses. To allow children to express their perceptions of PA visually, the researcher invited children to independently (i.e., not completed in conjunction with peers) draw an environment where they were most likely to participate in PA. The drawing took the focus away from direct questioning and consensus, to that of a more child-centred approach that better allowed for the lived experience to be shared (Horstman et al. 2008). Throughout the write and draw activity the researcher separately engaged children in informal conversations to allow them to articulate what they were drawing and why, for example:

*''And what about you Joe? Can you tell me what's going on in your picture?"*

With the exception of providing children with motivational comments to continue/complete as appropriate, the researcher refrained from providing any evaluation of the children's drawings. The write and draw activity provided children with greater control over their expression, allowing them to reflect upon and articulate what is important to them, and the drawings themselves are rich visual illustrations that directly represented children's perspectives and/or experiences (Enright & O'Sullivan, 2012; Gabhainn & Kelleher, 2002). Following the completion of the write and draw activity the WDST group proceeded with more challenging open-ended questioning around out-of-school PA and outdoor play. In the view that children enjoy and are satisfied most when speaking about their own personal interests and experiences the researcher provided children with various opportunities to speak about their individual PA interests and experiences and were encouraged to talk about themselves (Carnegie, 2006).

> *Can you tell me what sorts of physical activities you most like taking part in outside of school? What is it that you like most about this activity compared to other activities? 'Over the past week what sorts of physical activities have you done outside of school? Can you tell me where you did the activity and who it was with?*

It was anticipated that by providing children with multiple ways of expressing, 'in their own words', their personal perceptions and experiences it would place them at greater ease, and their increased comfort when expressing themselves would provide more honest and open discussion thereby enhancing data credibility (Carnegie, 2006; Glenn et al. 2013). Each WDST group comprised five children and lasted 40–55 (mean = 47.7) minutes. This number of child participants is similar to the sample sizes involved previous PA studies undertaken by the supervisory team and has been shown to be optimal in generating good-quality representative data (Mackintosh et al. 2011). Each of the WDST groups comprised children from the same school. On arrival at each school, the researcher randomly selected five consenting participant names to take part in a WDST group. The names of the selected children were provided to the class teachers at schools and children were excused from class to take part. The WDST groups took place in quiet non-intrusive school class rooms where participants and researcher could be overlooked but not overheard. All WDST groups were recorded using a digital recorder and were transcribed verbatim for further analysis and anonymised. In total, 7 WDST groups were conducted resulting in 242 pages of raw transcription data, Arial font, size 12, double spaced.

#### 6.2.2.2 School transport data

Active school travel contributes to children's daily PA levels but is strongly influenced by household distance from school (D'Haese et al. 2011; Van Dyck et al. 2010). To offer a more detailed insight into children's unstructured out-of-school PA the study assessed the prevalence of active travel as well as school-home distance. Household distance to school was objectively measured using Google maps online route planner https://www.google.co.uk/maps. The shortest route from school addresses to parent reported home addresses was used (Van Dyck et al. 2010). Transportation mode to school was child reported. Responses included (walk, cycle, scooter, bus, car, train, taxi, other). Responses were dichotomised into (0 reference category) active transport and (1) passive transport. Average participant travel distance from home to school was 1.51 km (Median = 0.9 km; IQR = 1.7 km).

### 6.2.3 Analyses

The WDST method generated three separate sources of data, a frequency count (show activity), visual data (write and draw activity) and verbatim data (tell activity and children's write and draw narratives). The separate data sources were pooled together for complimentary purposes in order to expand, enhance and clarify findings from each of the separate data sources. In this case, one stage did not inform the next, rather a mixed analysis approach was taken and in doing so the analysis strands did not interact until the data interpretation stage. For the 'show' data, child written responses were summed to produce frequency counts.' Tell' data were analysed through a deductive and inductive process, firstly using the YPAPM (Welk, 1999) as a thematic framework reflecting the underlying study objectives, and then inductively to enable emergent themes to be further explored (Biddle et al. 2001; Smith & Caddick, 2012). The pen profile approach has been used in recent child PA research (see Mackintosh et al. 2011) and presents findings from content analysis via a diagram of composite key emerging themes. For these reasons it is an appropriate and effective way of presenting data to researchers that have an affinity with both quantitative and qualitative approaches (Knowles et al. 2013; Ridgers, Knowles & Sayers, 2012).

A similar analysis approach was undertaken with the write and draw data. Drawings needed to be a legible representation of people, events, and/or places to satisfy quality standards. Children's narratives were transcribed verbatim, classified as a written 'report', and subsequently appended to each individual drawing. The reports and drawings were then used in combination to categorise 'marks' on paper in relation to specific themes (i.e., play, games, social interaction, environment). A 'mark' refers to where child 'reports' were identifiable with a 'theme'. In most cases each drawing identified more than one theme and thus more than one mark. For example, a drawing containing a child participating in a game of football with friends would require marks for more than 1 theme (both social interaction and activity).

To ensure accuracy and allow for alternative interpretations of the data, the WDST group recordings, transcripts and drawings were independently reviewed by two members of the research team and were then cross-examined against the data in reverse, from the pen profiles to the transcripts and write and draw data sheets. This process was repeated until a 90% agreement level had been reached by the group. Methodological rigor, credibility and transferability were achieved via verbatim transcription of data and triangular consensus procedures, and comparison of pen profiles with verbatim and illustration data accentuated dependability. In some instances, visual illustrations are presented to add further context to the data. Quotations are labelled by the participant's pseudonym, boy (B) or girl (G), and ID number. The key emergent themes identified from the data are presented first.

## 6.3 Results

### 6.3.1 Show and tell

In total 167 responses were reported for the show task. PA was most frequently associated with organised sports (e.g., football, basketball, gymnastics) ($n$ = 21), sport ($n$ = 17), running ($n$ = 17), swimming ($n$ = 8), cycling ($n$ = 3), exercise ($n$ = 8), fun ($n$ = 19), and health ($n$ = 13). Pen profiles representing children's perceived predisposing factors to out-of-school PA are presented in Figure 6.1, with two higher order themes of 'Am I able?' and 'Is it worth it?' linked to five higher order sub themes of competence +ve ($n$ = 4), fun +ve ($n$ = 5), enjoyment +ve ($n$ = 6), competence –ve ($n$ = 1), and enjoyment –ve ($n$ = 2). Positive (+ve) and negative (−ve) influences featured in predisposing secondary themes.

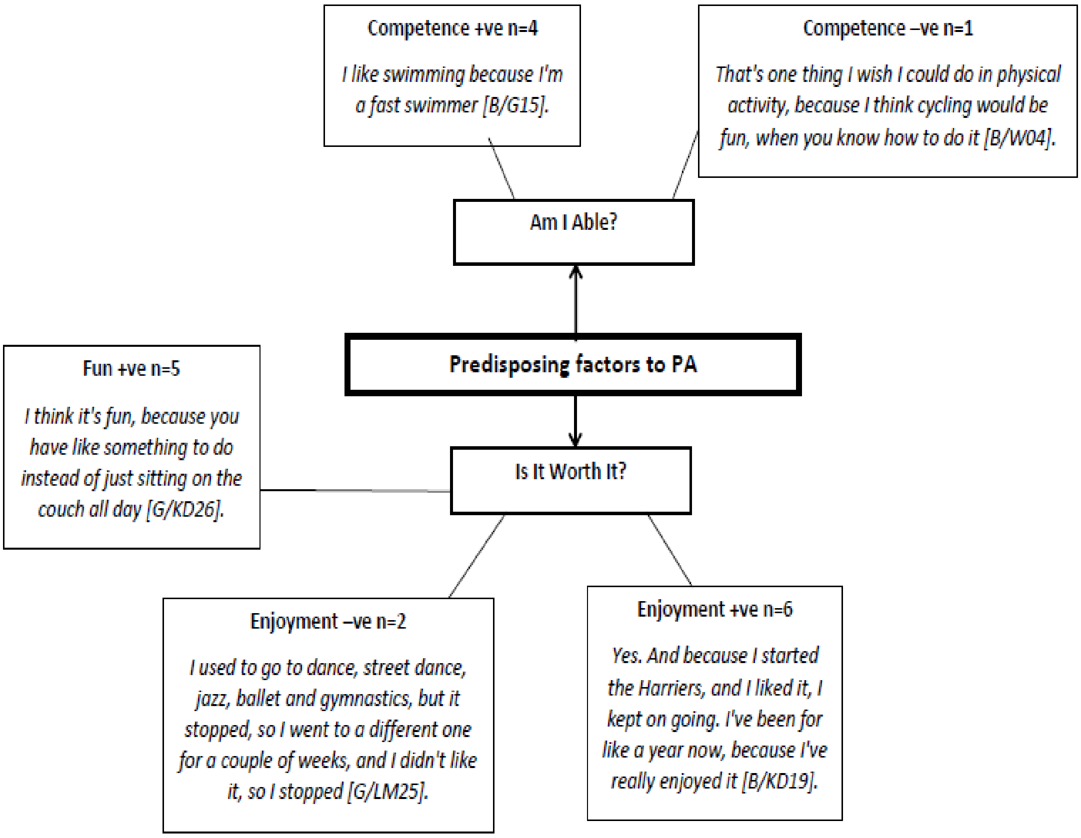



Figure 6.1 Children's perceived predisposing factors to out-of-school PA. +ve = positive. -ve = negative. M = Boy. G = Girl

Children's perceived reinforcing factors to out-of-school PA are presented in Figure 6.2, with five primary themes: parental support, parental role models, parental restriction, parental time constraints, and peers, and eleven secondary themes; financial support ($n$ = 2), co-participation +ve (e.g., PA together) ($n$ = 5), watching participation ($n$ = 2), verbal encouragement and praise ($n$ = 7), co-participation –ve ($n$ = 1), parental role models ($n$ = 3), parental time constraints ($n$ = 7), peer co-participation ($n$ = 7), limited friends ($n$ = 3), sedentary behaviour ($n$ = 3), grounding ($n$ = 1), stranger danger fear ($n$ = 3), and road traffic fear ($n$ = 4). Positive (+ve) and negative (−ve) influences featured in both reinforcing primary and secondary themes.

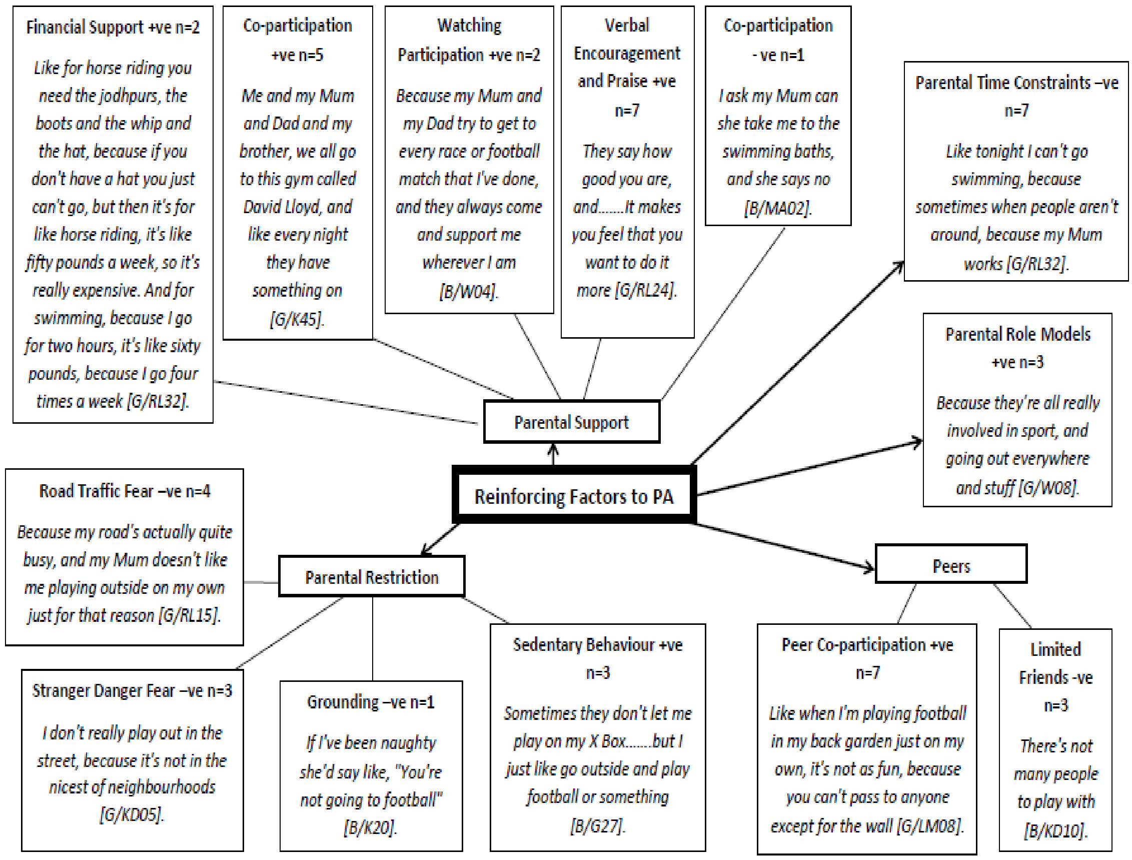



Figure 6.2 Children's perceived reinforcing factors to out-of-school PA. +ve = positive. -ve = negative. B = Boy. G = Girl

Children's perceived enabling factors to out-of-school PA are presented in Figure 6.3. There were five primary themes; environmental factors, physical ability, time, sedentary devices and dog ownership, and twelve secondary themes: weather ($n$ = 4), seasonality variation ($n$ = 2), school ($n$ = 2), weekend ($n$ = 7), tired ($n$ = 2), illness and injury ($n$ = 2), proximity +ve ($n$ = 7), proximity –ve ($n$ = 2), provision +ve ($n$ = 7), –ve ($n$ = 2), provision quality +ve ($n$ = 4), and provision quality –ve ($n$ = 2). Positive (+ve) and negative (−ve) influences featured in enabling secondary themes.

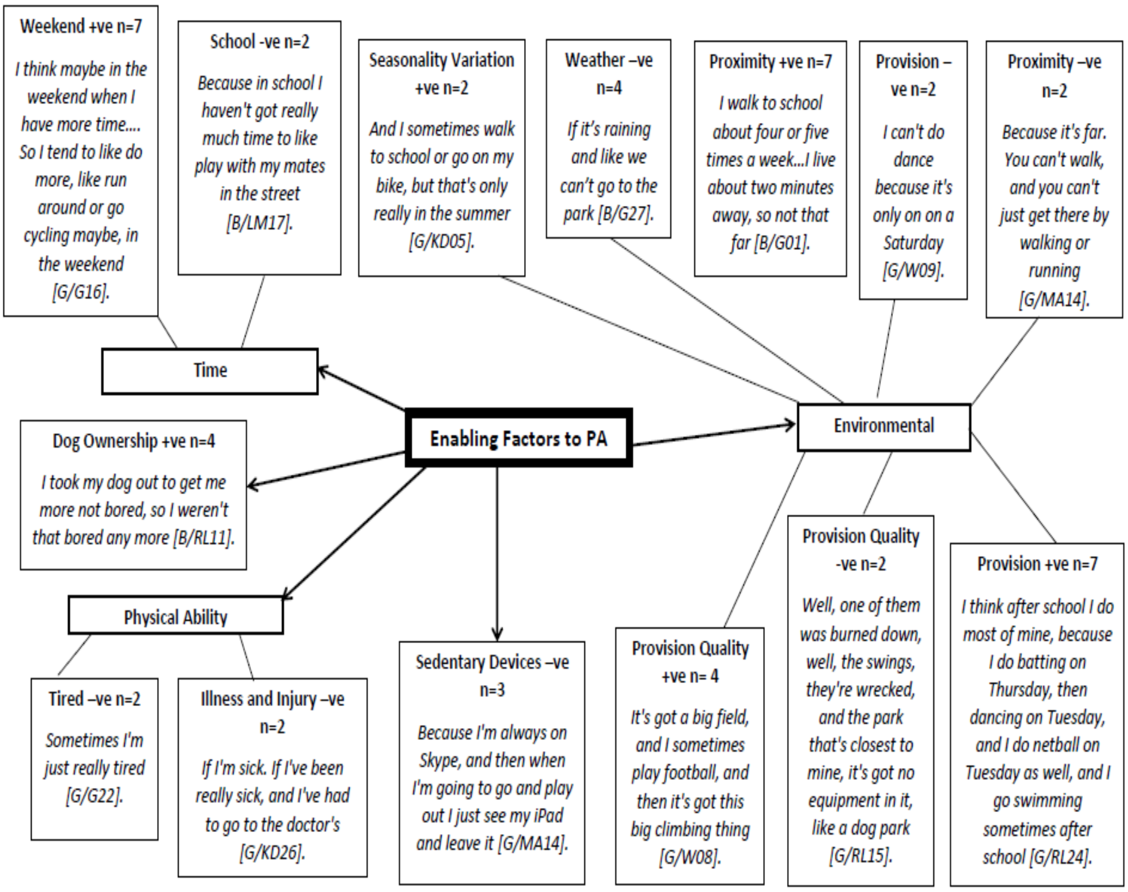



Figure 6.3 Children's perceived enabling factors to out-of-school PA. +ve = positive. -ve = negative. B = Boy. G = Girl

### 6.3.2 Write and draw

Thirty children completed the write and draw task (14 boys), and 30 reports were extracted with 5 blank reports and 0 indefinable entries. Blank returns were due to insufficient time in one WDST group to complete the task. There were 88 marks from reports on specific themes. Figure 6.4 illustrates the composite pen profile with activity (*n* = 24), social interaction (*n* = 18) and physical environment (*n* = 46) as highest frequency themes. PA equipment (*n* = 20), PA provision (*n* = 26), friends (*n* = 14), parents (*n* = 4), unstructured play (*n* = 9), games (*n* = 13), and recreational activities (*n* = 2) featured as lower order themes.

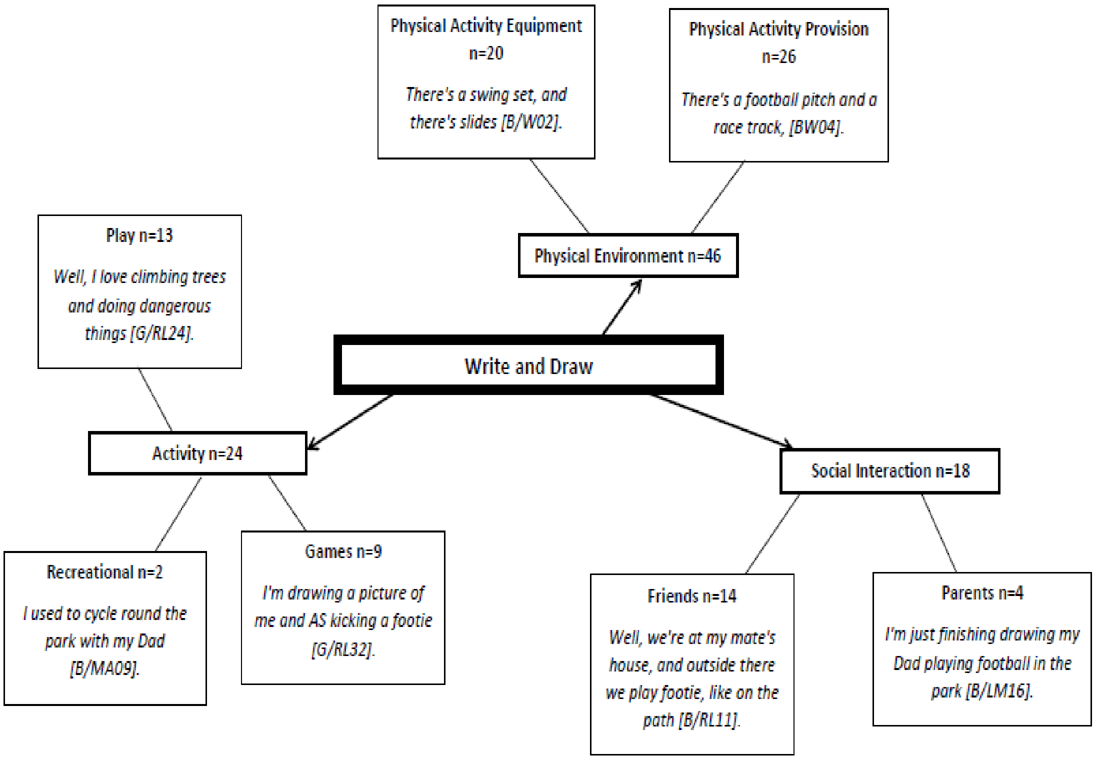



Figure 6.4 Write and Draw. +ve = positive. -ve = negative. B = Boy. G = Girl

Sixty percent of children commuted actively to school. Eighty one percent and 95.2% of these children lived within 1.0 and 2.0 km from school, respectively. The other 4.8% lived within 3.0 km. Almost 30% of the passive commuters lived within 1.5 km from school.

### 6.4 Discussion

The primary aim of this study was to explore children's current views, experiences and perceptions of out-of-school PA. PA intervention design is centred on identifying factors that facilitate and inhibit children's participation, but research featuring that of the child's voice is presently lacking. Using children's views, recounted experiences and perceptions of out-of-school PA the research presented here demonstrates how WDST may be advantageous when compared to more traditional singular methods based approaches (Darbyshire, MacDougall & Schiller, 2005). WDST's principal strength is its triangulation of multiple data sources which generates a rich data set representing 'children's voices' and in doing so enhances data credibility strengthening the evidence on the phenomenon under investigation.

### 6.4.1 Predisposing factors

Consistent with other studies (Sebire et al. 2013; Timperio et al. 2013), children in this study principally engaged in PA for reasons of fun and enjoyment. Within self-determination theory (SDT) (Deci & Ryan, 1985; 2000), autonomous forms of motivation such as intrinsic motivation exist when the behaviour is viewed as enjoyable. In this study, the competitive and vigorous nature of organised physical activities appeared particularly appealing and enjoyable for many children as they perceived them to be more engaging and beneficial to physical health.

> *I like football, I like swimming. You have to keep healthy when you're doing sport. It's good fun. It's healthy for your body, your body will grow hard and tough, and it just builds your body up to get stronger [G/RL32].*

In line with SDT (Deci & Ryan, 1985; 2000), children's PA self-perceptions (i.e., self-efficacy and perceived competence) were both key influences on PA enjoyment and participation, with children expressing a sense of enjoyment towards activities that they are 'good' at. Children with higher self-perceptions possess higher motivation to be physically active and approach PA related tasks with a high expectancy of success, leading to greater perseverance and enjoyment in PA than children with low PA self-perceptions (e.g., Craggs et al. 2011; Van der Horst et al. 2007). Although children's sense of competence can be related to both perceived PA skill and experience, evaluative feedback from significant others, largely that of parents, but also friends, is understood to be of particular importance (Ryan et al. 2009). Alternatively, activity monitors such as pedometers provide feedback reflecting individual activity behaviour and serve as a tool to self-monitor and set personalised goals. Increasing self-efficacy by providing feedback about PA may effectively increase PA in children (Horne et al. 2009; Lubans, Morgan & Tudor-Locke, 2009).

### 6.4.2 Enabling factors

Almost all children reported PA access and provision availability as key PA facilitators. The weekday after-school period provided children with the greatest perceived access to clubs and recreational facilities and with this in mind, many children consequently determined after-school as one of their most active time periods. The weekend was also linked to high activity with greater opportunities for competitive sport participation (particularly football) and family-based activities such as bike riding and walking relative to other periods of the week. Children credited this to both them and their parents having greater discretional time to partake in PA on weekend days. Such findings are in contrast to recent quantitative studies that reported significant declines in PA during out-of-school periods compared to other periods (Telford et al. 2013; Vander Ploeg et al. 2012). These conflicting findings could be attributed to children not accounting for the unstructured PA they participate in throughout the school day on the playground and their active transport to and from school.

Indeed, few children in this study accounted for engagement in unstructured forms of PA such as active travel, dog walking or active play, even though 60% of participants walked to school regularly. As seen in the show data, children generally attributed PA with sport, which was confirmed within the write and draw data, with children expressing a greater recollection of structured physical activities, games (i.e., football) [refer to Figure 6.4]. Interestingly, almost 30% of children in this study live within 1.5 km of the school yet do not commute to school actively. Active commuting to school and to other activities is associated with improved health (Saunders et al. 2013), fitness (Larouche et al. 2014; Lubans et al. 2011; Voss & Sandercock, 2010) and energy balance (Mendoza et al. 2011; Mendoza & Liu, 2014), and serves as a valuable opportunity for children to significantly increase daily PA levels (Faulkner et al. 2013; Lee & Li, 2014; Roth, Millett & Mindell, 2012). Increasing children's and parents' awareness of the various forms of PA such as active travel and unstructured play, and how these contribute to children achieving daily PA recommendations is warranted.

The visual and verbal data generated from the novel dual methodology revealed new insights and shed light on aspects of the built environment that support children's out-of-school PA which may have been overlooked in previous surveys (Veitch, Salmon & Ball, 2008; 2010) and singular qualitative methods based studies (Brockman et al. 2009; Stanley, Boshoff & Dollman, 2012). Public parks were a popular location for PA but proximity to public parks influenced regular park use among children, especially unsupervised park visits. In addition to accessibility, the quality of provision and playground equipment at parks was related to children's park use and also their experience, with children expressing a greater sense of enjoyment when there was a high prevalence of playground equipment at local public parks. Moreover, the provision of grassed areas and playground equipment appeared fundamentally important to children's PA within drawings [refer to Figures 6.4 and 6.5], so much so, many children reported travelling with parents to parks farther afield that are larger in size and have 'better' provision. The narrative complementing children's drawings verified the content in drawings, and added context to the drawings by revealing insights on the reasons for the inclusion of specific content [refer to Figure 6.5]. Such supplementary data would have been overlooked using traditional write and draw analysis approaches and may have influenced study findings. For example,

> *I like grass, because I just think it's easy to do things on, and you can do quite a lot of things, whereas concrete, it's quite dangerous, and you could fall. And I like climbing trees.....and a gymnastics bar, because me and my sister, we use the bar where you swing, and you do like flips and stuff, because me and my sister, she's younger than me, we've got this swing, and it's high, well, about this high, and we like climbing up to the top of it and swinging, and doing flips on it, so I like that. And I'd like a netball post, because I like netball and stuff like that, and lots of bushes, so we could play hide and seek [G/RL24].*


Figure 6.5 Drawing from a girl aged 11 illustrating activity equipment and provision

Furthermore, although some children reported creative methods to overcome a lack of equipment, such as using clothing as goal posts, they also reported that greater availability of adequate provision (i.e., goal posts and designated green space areas) would further enhance their activity enjoyment. In order to promote regular park use among children and families a variety of features within parks may be required to support the needs of different family members (Edwards et al. 2015; Kaczynski, Potwarka & Saelens, 2008). Future formative studies may benefit from using a similar methodology to that used here, especially those planning environmental interventions.

Proximity also influenced school transport mode in this study. Most school walkers appeared to have a high level of independent mobility, with the majority of children walking to school either alone, with siblings, or friends. While this may be because of the relatively short distance to school (D'Haese et al. 2011; Faulkner et al. 2013), it could also be due to the presence of siblings and/or or friends which have both been associated with children’s increased independent mobility (Mackett et al. 2007; Zwerts et al. 2010). In addition to the health benefits of walking to school (Lubans et al. 2011), unescorted school trips could be used as a stepping stone to broader independent mobility (i.e., outdoor play) by developing parents’ reassurances (Stanley, Maher & Dollman, 2015). For example:

> *Well, in the car you're just sitting there, and then on a bike you're actually like it's fun, and you're actually getting something from it because it's good for you, and it's better than just getting in the car and just driving [G/KD45].*

Despite home gardens/yards being a safe, popular and convenient location for children’s PA (Veitch, Salmon & Ball, 2010), the size of the enclosed space limited the activities that children engaged in and consequently influenced whether children used their garden/yard regularly for PA in this study. Although not investigated here, the absence of a garden/yard may promote greater neighbourhood play among children (Aarts et al. 2010). Consistent with previous findings, the neighbourhood environment for some children was another prime location for PA (Barron, 2013). This was especially true for children living in cul-de-sacs and those living away from main roads, owing to higher independent mobility from parents. However, for most children unsupervised outdoor play was restricted because of parental fear regarding road traffic and children being ‘taken by strangers’. Such findings add to the existing body of evidence on social and built environmental influences (D’Haese et al. 2011; De Meester et al. 2014; Lee et al. 2015; Janssen, 2014; Rader et al. 2015), and in particular, cul-de-sac residency (Veitch, Salmon & Ball, 2008; Hochschild, 2012) on children’s independent mobility and play behaviours.

Although low neighbourhood street connectivity (i.e., intersections) is associated with lower child (Giles-Corti et al. 2011) and adult walkability (Koohsari et al. 2014), it also reduces motorised traffic volumes, providing a safer open area for children to engage in outdoor play (e.g., football, tag) in close proximity to their home (Mecredy, Pickett & Janssen, 2011; Tappe et al. 2013). Creating safe play spaces free of motorised traffic in neighbourhoods could also be an effective way of increasing children’s independent mobility and in turn increasing PA, partly by shaping parents’ perceptions of their children’s safety (D’Haese et al. 2015b; Farley et al. 2007; Villanueva et al. 2013). Such neighbourhood improvements may be particularly important for younger children and children without a garden/backyard and/or limited access to recreational green space. Moreover, providing connections between streets that are only accessible by foot rather than motorised transport may also provide a neighbourhood environment conducive to children's play and active travel for both children and adults and should be considered by future urban planners. These findings support the need for continued traffic calming and safer route measures to alleviate parental safety concerns and support UK children's outdoor play and active travel (Randolph & Benjamin, 2014; Stewart, Moudon & Claybrooke, 2014).

Quantitative research has shown that children who are provided with the freedom to travel actively and play outdoors independent of adult supervision accumulate more PA (Faulkner et al. 2015; Schoeppe et al. 2014) and have better health than those who do not (Gray et al. 2015; Schoeppe et al. 2013a; Stone & Faulkner, 2014). This study however revealed some insight into how children gain access to outdoor play and the practices used by parents to build trust and manage the perceived risks posed to children outdoors. Firstly, children in this study that were allowed to play outdoors regularly in the neighbourhood reported spatial and temporal boundaries placed on their outdoor play. For example:

> *Because I can play out, but my Mum has like a thing that I have two lampposts, and I'm not allowed to go past them [B/K13].*

Moreover, children were provided with greater independent mobility when playing with friends or at nearby recreational areas [refer to Figure 6.6]. The presence of other children playing out in the neighbourhood may help to reduce heightened parental neighbourhood safety concerns by way of safety in numbers (Holt et al. 2015). Children in this study whose parents were anxious about allowing them to travel to recreational areas alone or with friends through fear of them being taken by strangers were dependent on their parents having the time and motivation to take them to recreational areas to be active. Children's licence to play outdoors may be dependent on locally constituted beliefs about 'good parenting', with some parents restricting their children from playing outdoors through fear of challenging the social norm, irrespective of their own personal neighbourhood safety perceptions (Christian et al.

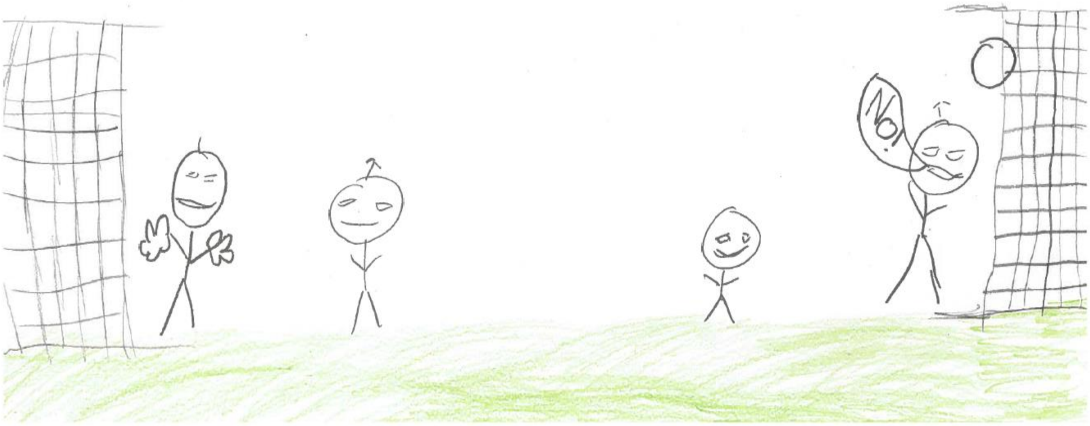
2015; Sutton, 2008). As key gate keepers to children's outdoor play, parents' qualitative input is warranted to explore the relationship between UK children’s independent mobility and neighbourhood social norms by socioeconomic background.


*Well, we're at my mate's house, and outside there we play footie, like on the path [B/RL11].*

Figure 6.6 Drawing from a boy aged 10 illustrating outdoor play close to home

### 6.4.3 Reinforcing factors

Consistent with prior quantitative research (Jago et al. 2009a; 2011), peer support was a key influence on children’s PA and the presence of friends was a central theme throughout children’s drawings [refer to Figures 6.4 and 6.7]. The dual methods used here revealed that friends provided social support in the form of co-participation (i.e., engaging in activity together), and their presence enhanced activity enjoyment and added greater meaning to PA. For example, when children alluded to playing games such as football it was in the context of playing football with friends rather than playing alone.



*‘M in goal, me, and N and little D. Because they're my mates, and, like I say, I always play football with them’ [B/K20].*

Figure 6.7 Drawing from a boy aged 11 illustrating playing football with friends

Moreover, friends also played a critical role in setting children’s PA patterns as documented in previous quantitative studies (Gesell, Tesdahl & Ruchman, 2012; Salvy et al. 2008). The narrative reported here however offered explanations as to why this may be. Being of similar age was important for children as it increased the likelihood of possessing similar PA interests. Also, outdoor play levels were dependent on other children living in the neighbourhood, with some children reporting declines in their outdoor play following friends moving home out-of-the neighbourhood, whereas others reported increased outdoor play levels following moving home to neighbourhoods where similar aged children played outdoors regularly. For example:

*‘Well, where I used to live there was loads, but because I was about six, five, and they were like nine and all that, so they didn't really want to play with me and my little sister, because we're like little, but now we've got someone called L, and she is in this class, and my sister's in Year Four, and I've got a friend who's in BS, and she's in Year Five, and then I've got RL32 and all that [G/RL15].*

Recent experimental and observational research found that the presence of friends significantly increased children's PA enjoyment (Jago, Page, & Cooper, 2012; Salvy et al. 2012), motivation (Salvy et al. 2009), intensity (Barkley et al. 2014), and out-of-school PA engagement (Pearce et al. 2014). Together, these and our findings suggest that future interventions promoting PA with friends and encouraging greater social interaction particularly outside of school may be a promising approach to increasing PA levels among UK children.

A recurring theme throughout the data was children's significant need for parental support. Parental support is a consistent correlate of child PA (Beets, Cardinal & Alderman, 2010; Mitchell et al. 2012) but research underpinning how parental support influences children's out-of-school PA is scarce. This study found that parents supported children's PA in a variety of ways; however, verbal encouragement appeared to have the greatest effect on children's emotions and their PA. Verbal support ranged from parents encouraging children to play outdoors instead of spending prolonged time indoors, to offering positive encouragement to children when considering ceasing PA participation. Both appeared to play a key role in influencing children to engage in more PA. Although logistical forms of support are consistent correlates of child PA (Mitchell et al. 2012; Beets, Cardinal & Alderman, 2010; Määttä, Ray & Roos, 2014), their limited presence within the current study data suggests that they play a less influential role on children's PA relative to verbal methods. Given that parental verbal encouragement is highly amenable to change, future PA promotional strategies directed towards increased verbal encouragement informed by improving parental knowledge of how and where to be active in the local neighbourhood may prove useful in increasing children's PA levels, particularly for children whose parents face physical, financial, or time restrictions (Bentley et al. 2012; Edwardson & Gorely, 2010b; Tate et al. 2015).

It was apparent from the data that active parents, particularly fathers, were a strong motivator for children's PA, despite the inconsistent relationship within the quantitative literature (Biddle et al. 2011a; Jago et al. 2014). Moreover, the direct involvement of parents in physical activities with children was also influential on children's PA behaviour, which supports previous findings (Atkin et al. 2013; Beets & Foley, 2008).

*Sunday my parents help me to do more physical activity when we go for a walk over the weekend. When I joined the Harriers (running club)…I would go with my Dad, because we both like running [B/G02].*

Children's drawings complemented such findings. Interestingly though, when parents were included in drawings it was fathers that were cited more frequently than mothers. One drawing in particular included a father engaged in PA with his two sons whereas mother was sitting down watching suggesting that, as portrayed here, some children may associate PA co-participation with fathers relative to mothers [refer to Figure 6.8]. Beets & Foley (2008) found that the amount of time fathers spent with their children was positively related to children's PA. In light of our findings and recent qualitative (Zahra, Sebire & Jago, 2015) and experimental research (Morgan et al. 2014), father-child co-participation may be an effective strategy for improving children's PA. However, to appeal to all familial structures, future family-based interventions should consider encouraging parents to engage in more PA with their children. The weekend period may be an appropriate time to encourage PA between parents and children due to children not attending school and parents having fewer work responsibilities. With regards to family recreational activity, popular activities included walking, swimming and visiting public parks. Public parks play an important role in supporting PA, providing all families regardless of socioeconomic position with the opportunity to walk, cycle, and many have specific equipment for other health enhancing physical activities (Cohen et al. 2007; Han, Cohen & McKenzie, 2013). Promoting greater use of public parks together with information relating to fun and enjoyable activities that families can engage in together may increase park use and PA among families (Buchner & Gobster, 2007).


*I'm just finishing drawing my Dad playing football in the park. I'm going to draw some little kids playing on the park' [B/LM16].*

Figure 6.8 Drawing from a boy aged 10 illustrating family-based PA

Although a range of inhibiting factors including weather and school were identified by children in relation to out-of-school PA, the adverse influence of parents was consistent across all WDST groups. Children's inability to access PA provision without the presence of their parents due to parental time constraints was a key participation barrier. Providing children and families with information on how children can best incorporate low cost PA into their daily lives such as walking and cycling to school or unstructured PA rather than structured activities that require parental presence and logistic support may be useful. Correlates research has found that children who experience fewer parental restrictions on their screen time spend significantly greater time sedentary indoors (Brindova et al. 2014; Carlson et al. 2010; Cillero & Jago, 2011). In this study, screen time acted as a barrier to PA, particularly during weekends when children had more discretionary time and autonomy over their sedentary pursuits due to no schooling and less structured activity provision. Interestingly, children reported higher levels of PA when parental restrictions were placed on their TV viewing and console game use in response to boredom, suggesting that parental monitoring of children's screen-time may be another important parenting practice to target in future family-based intervention strategies.

> *Sometimes they don't let me play on my X Box……., but I just like go outside and play football or something [B/G27].*

Given that parental sedentary behaviour restriction had a positive effect on children's PA in this study with children opting to play outdoors, educating parents to encourage children to play outdoors more regularly with friends rather than confining children to the home environment could be a cost effective and potentially valuable means of increasing PA, reducing sedentary time, and improving health in UK children (Vandewater et al. 2015). Advocating play and emphasising outcomes such as positive social, emotional, and cognitive well-being rather than simply the physical dangers of its absence (i.e., obesity), may resonate more strongly with parents when suggesting that their child be more active, particularly outdoors (Burdette & Whitaker, 2005b).

Several strengths are apparent in the present study. The development of a dual method, named here as WDST respected the expert knowledge of the children, allowed for a deeper insight of children's experiences and perceptions, and in doing so generated a rich data set representing 'children's voices' (Kesby, 2007). Most importantly, the combination of methods enhanced data credibility, and revealed interconnected and complementary findings on children's views, experiences and perceptions of out-of-school PA that would have been overlooked via survey, adult focussed, or single qualitative methods based research. Whilst the write and draw method has been used extensively in health related research a lack of consensus around analysis has led to questions regarding its validity (Angell, Alexander & Hunt, 2015). Alternatively, the researcher listened to children as they drew and explored the narrative elicited from children's drawing which recognised the social context and verified content in the drawings (Dockett & Perry, 2005; Angell & Angell, 2013). Moreover, the triangulation of children's drawings and supporting narrative meant that the analysis was not solely dependent upon the researcher's interpretation of the data, and in doing so, reduced the risk of misinterpreted views, improved data credibility, and enhancing confidence in the findings (Darbyshire, MacDougall & Schiller, 2005; Smith & Noble, 2014).

Further methodological strengths include the pen-profile analyses, which illustrate accurately the consistency of themes in the data, rather than over-representing minority views, and the supplementary verbatim quotations verified children’s voice (Anderson, 2010). Moreover, the triangulation consensus of data between the research team provided credibility, transferability, and dependability, and the audit trail presented here clearly outlines and justifies comprehensively the methodological decisions made throughout the study providing transparency and trustworthiness, enabling future studies to adopt a similar methodological approach (Carcary, 2009). In addition, this research advances previous qualitative studies by extended the literature base on children’s out-of-school PA by considered all components of the YPAPM (Welk, 1999) including the influence of peers and independent mobility, which provides new insights into an understudied area. With regards to limitations, the influence of participant bias may limit the generalisability of findings, with only 34.8% of eligible participants providing informed consent and assent, and 19.1% taking part.

### 6.5 Conclusion

The WDST method generated complimentary interconnected data, which was theoretically grounded, and confirmed and uncovered new insights into factors relevant to children’s out-of-school PA. Specifically, the findings of this study enhance understanding of the mechanisms through which parents influence children’s activity related behaviours, and provide an insight into potential target areas for future out-of-school PA interventions aimed at primary school aged children. Parental involvement in future PA promotional strategies is essential given that paradoxically, parents served as both significant enablers (i.e., encouragement) and barriers (i.e., restricting participation) to children’s PA in this study. The findings of this study concur with those of others who report parents are PA gatekeepers, ‘choice architects’, and governors of the home environment and as such, are in a key position to promote behaviours that are conducive to children’s health (Maitland et al. 2013; 2014; Thaler & Sunstein, 2008). Thus, parents' qualitative input is important to supplement children’s voices and inform future family-based intervention design (Teedon et al. 2014). Our findings suggest that children should be encouraged to spend more time with friends and play outdoors more. Increasing children’s levels of unstructured PA such as active transport and active play is warranted, but is likely to be mediated by parental license, and be dependent upon community and societal level changes to create safer neighbourhood spaces (Little, 2015). Further experimental evidence is needed to establish whether changes in parental neighbourhood perceptions positively increase children's opportunity to engage in independent active travel and outdoor play.

The WDST methodology developed here is an inclusive, interactive, and ethically compliant child-centred dual research method that enhances credibility by triangulating data sources and limiting researcher biases. It thus serves to benefit future researchers and practitioners aiming to elicit children's perceptions and experiences. Further research applying WDST is needed within PA and health contexts to further validate its appropriateness and assist in its evolution as a child-centred method.

**Thesis study map**

| **Study** | **Objectives and key findings** |
|---|---|
| Study 1: Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. | **Objectives:**<br><br>(1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation.<br><br>(2) To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.<br><br>**Key findings:**<br><br>• High deprivation children had higher BMI z-scores and waist circumference and lower CRF compared to medium-to-high deprivation children.<br>• High deprivation children lived in less walkable neighbourhoods and were less likely to have access to a garden than medium-to-high deprivation children.<br>• PA was inversely associated with bedroom media and positively associated with independent mobility.<br>• Independent mobility was inversely associated with crime safety and neighbourhood aesthetics. |
| Study 2. Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week. | **Objectives:**<br><br>(1) To assess children's physical activity levels derived from wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data. |

| | |
|---|---|
| | (2) To examine the comparability of physical activity levels between the two devices throughout the segmented week.<br><br>**Key findings:**<br><br>• Children's raw PA levels were lowest on weekend days.<br>• Wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ derived raw PA levels are not comparable in children.<br>• The largest differences in GAwrist and AGhip derived raw PA were observed at the lowest intensity and during school hours. |
| Study 3. Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity. | **Objectives:**<br><br>(1) To use a novel combination of qualitative techniques to explore children's current views, experiences and perceptions of out-of-school physical activity as well as offering formative opinion about future intervention design.<br><br>**Key findings:**<br><br>• Parents served as both enablers (i.e., encouragement) and barriers (i.e., restricting participation) to children's PA.<br>• Involvement of parents and the whole family is a strategy that could be significant to increase children's PA levels.<br>• WDST is an inclusive, interactive and child-centred methodology which facilitates the exploration of a wide range of topics and enhances data credibility. |

| | |
|---|---|
| Study 4. Parental perceptions on children’s out-of-school physical activity and family-based physical activity. | **Objectives:**<br><br>(1) To explore parents' PA knowledge and perceptions of children’s out-of-school PA to formatively contribute to a family-based intervention design. |
| Study 5. Context matters! Sources of variability in weekend physical activity among families: A repeated measures study. | |

# Chapter 7

# Study 4:

# Parental perceptions on children’s out-of-school physical activity and family-based physical activity

The main outcomes of this study have been published in *Early Child Development and Care*: Noonan, R. J., Boddy, L. M., Fairclough, S. J., & Knowles, Z. R. (2016). Parental perceptions on children's out-of-school physical activity and family-based physical activity. *Early Child Development and Care*. doi: 10.1080/03004430.2016.1194409. The published article can be found in Appendix A.

## 7.1 Introduction

Independent mobility was positively associated with children's self-reported PA in Chapter 4 and served as a key facilitator to out-of-school PA in Chapter 6. However, the preceding Chapters have offered limited exploration of the factors that influence parents' decision-making towards children's out-of-school PA and independent mobility. Qualitative methodologies allow for perceptions and attitudes to be explored and can present an effective way of understanding how parents participate in and facilitate children's PA (Jago et al. 2012; Mackintosh et al. 2011). Recent UK qualitative findings on children's PA relate largely to young children (Kesten et al. 2015) and the perceptions of low-income and/or ethnic minority parents (Eyre et al. 2014; Trigwell et al. 2015). Aside from being unrepresentative of older children and those from more affluent neighbourhoods, these findings may also have been socially biased given the presence of other parents. Compared to focus groups and face-to-face interviews, telephone interviews are a convenient method for parents to engage in, reduce the risk of socially desirable responses and facilitate more open discussion around potentially sensitive topics such as parental engagement in children's PA (Sturges & Hanrahan, 2004).

Family-based health programmes generally struggle to recruit and retain families which often results in programmes reaching a small proportion of the target group who are often those least in need of behaviour change (Mytton et al. 2014). Exploring the attitudes, norms and perceptions of families (i.e., children and parents), and consulting with them in a formative sense to that of intervention design, is central to a phased approach to complex intervention development (Craig et al. 2008), may help to overcome key intervention challenges including recruitment and engagement, and thus could improve intervention efficacy (Davison et al. 2013; Jago et al. 2013a). Although some studies have explored family-based PA intervention recruitment and retention strategies (Bentley et al. 2012;

Brown, Schiff & van Sluijs, 2015; Jago et al. 2012), little consideration has been given to parents' concurrent PA knowledge or perceptions which may also have important implications on perceived intervention relevance, uptake and design.

This study compliments Chapter 4 and 6. Chapter 4 examined associations between home and neighbourhood environments and 9–10 year old children's PA, and Chapter 6 explored 10–11 year old children's views, experiences and perceptions of out-of-school PA. Moreover, this study will build upon previous research methodologies by triangulating data sources to explore parents' PA knowledge and perceptions of children's out-of-school PA to formatively contribute to a family-based intervention design.

## 7.2 Study specific methods

### 7.2.1 Participants and setting

Participants for this study were self-reported parents of Liverpool schoolchildren aged 10–11 years. Parents were eligible to take part in the study if they had previously completed a questionnaire investigating their neighbourhood perceptions and their child had completed prior anthropometry, CRF and PA assessments (study 1). Following the recruitment of seven primary schools, all eligible children (*n* = 181) aged 10-11 years in participating schools were given an information pack containing a parent information sheet and consent form to take home to parents to be completed. Forty-five parents (24.9% response rate) consented to take part in a telephone interview. The researcher compiled a list indicating parents' willingness to take part and a convenience sample was utilised for this study based on which parents could be contacted first. Data were collected throughout January and February 2015.

### 7.2.2 Measures and procedures

#### 7.2.2.1 Telephone interviews

Semi-structured interview guides were used to ensure consistency across interviews, and questions were informed by the YPAPM (Welk, 1999). The telephone interview questions centred on three main topics; parent PA knowledge, child PA and independent mobility, and family-based PA. For the latter topic, parents were provided with a description of a family-based PA intervention programme and asked whether they would consider participating in a similar programme in the future. Parents were subsequently asked to explain what factors would motivate them to take part in a family-based PA intervention programme, and what factors would restrict them from taking part in a family-based PA intervention programme. Example telephone interview questions included, ‘can you think of any barriers that prevent your child from doing more PA? What sorts of PA provision and activities are there for your child to do close to home in your neighbourhood?’ Prior to data collection, consenting parents were sent an SMS by the researcher to inform them that they would be contacted in the evening from a withheld telephone number. Parents were given the option of a specific day or time to be contacted to carry out the telephone interview. Only one participant chose a specific time to be contacted. All telephone interviews were recorded using a digital recorder and were transcribed verbatim and anonymised. Parents received a £10 high street shopping voucher in return for their participation. In total, 11 (female $n$ = 8) (6.1% response rate) telephone interviews were conducted with consenting parents from across 3 primary schools lasting 10–20 (mean = 15.4) minutes resulting in 125 pages of raw transcription data, Arial font, size 12, double spaced.

#### 7.2.2.2 Demographic data

Parents completed the International Physical Activity Questionnaire short form (www.ipaq.ki.se) and reported their age, marital and educational status, stature, and body mass. The latter were used to calculate BMI (kg/m$^2$) and weight status (i.e., healthy weight or overweight/obese) (World Health Organization, 2000). Data for child sex, ethnicity, body mass, BMI, BMI z-score, waist circumference, self-reported PA, CRF, area level deprivation, garden/backyard access, transport mode to school and household distance to school for relevant children collected and described in study 1 (Chapter 4) and 3 (Chapter 6) were used within this study to enable the construction of descriptive family case studies. Average participant travel distance from home to school was 1.4 kilometres (Median = 0.9 kilometres; IQR = 1.2 kilometres). Means, standard deviations and percentages were calculated for continuous and categorical variables, respectively. All analyses were conducted using Microsoft Excel 2010 (Microsoft, Redmond, WA) and IBM SPSS Statistics v.22 (IBM, Armonk, NY).

### 7.2.3 Analyses

Regardless of the qualitative analytical approach used, for example, ‘cut and paste’, manual tagging or NVivo software, there appears to be no impact on study validity (Krane, Andersen & Strean, 1997). After listening to the interview recordings and reviewing the transcripts the researcher generated a series of higher and lower order themes based on the aims of the study and the themes that emerged. Pen profiles were constructed to represent the higher and lower order themes using a manual approach, and verbatim quotations were subsequently used to expand the pen profiles, provide context and verify participant responses (Knowles et al. 2013). To ensure accuracy and allow for alternative interpretations of the data, the recordings and transcripts were listened to by two members of the research team and were then cross-examined against the data in reverse, from the pen profiles to the transcripts. This process was repeated until a 90% agreement level had been reached by the group. Methodological rigor, credibility and transferability were achieved via verbatim transcription of data and triangular consensus procedures, and comparison of pen profiles with verbatim data accentuated dependability. Quotations are labelled by the participant’s pseudonym, male (M) or female (F), and ID number.

To offer a more detailed insight into parental PA perceptions, knowledge, and family context beyond traditional qualitative analysis approaches, the research triangulated child and parent data and parent narratives, and descriptive family case studies were written. The case study families were purposively selected based on their family structure and PA perceptions. Prior to writing the case studies, the quantitative and qualitative data were assessed by the research team and consensus was reached that the selected families would allow for the study aims to be achieved. The case studies demonstrate how parent perceptions and family constraints can influence children’s out-of-school PA levels and activity mode. Demographic information in conjunction with verbatim narrative for contrasting family structures with alternative perspectives on children’s out-of-school PA are presented alongside the pen profile data (Boxes 7.1 and 7.2).

### 7.3 Results

Most of the parents interviewed were female (72.7%), parents to boys (81.8%), married (90.9%) and degree educated (81.8%). Their children were of white ethnic origin (100%), normal weight status (100%) and lived in higher than average socioeconomic status neighbourhoods reflected by the low mean IMD score for the sample (19.6 compared to English average of 23.6) (Department for Communities and Local Government. 2015). Most of the children had access to a garden/backyard (81.8%), commuted actively to school (63.6%) and lived within one kilometre from school (63.6%). The self-reported PA levels (3.5 ± 0.6 compared to 2.8) (Voss, Ogunleye & Sandercock, 2013) and CRF scores (52.6 ± 23.2 compared to 29 shuttles) (Boddy et al. 2012) of the participants were higher than the English averages.

Pen profiles representing parental PA knowledge are presented in Figure 7.1, with three primary themes: PA health benefits, PA levels and PA guidelines, and eight secondary themes: physical ($n$ = 11), psychological ($n$ = 7), social ($n$ = 1), behaviour ($n$ = 2), know (yes $n$ = 4; no $n$ = 7) and meet PA guidelines (yes $n$ = 6; no $n$ = 5). Positive and negative influences featured in parental knowledge secondary themes.

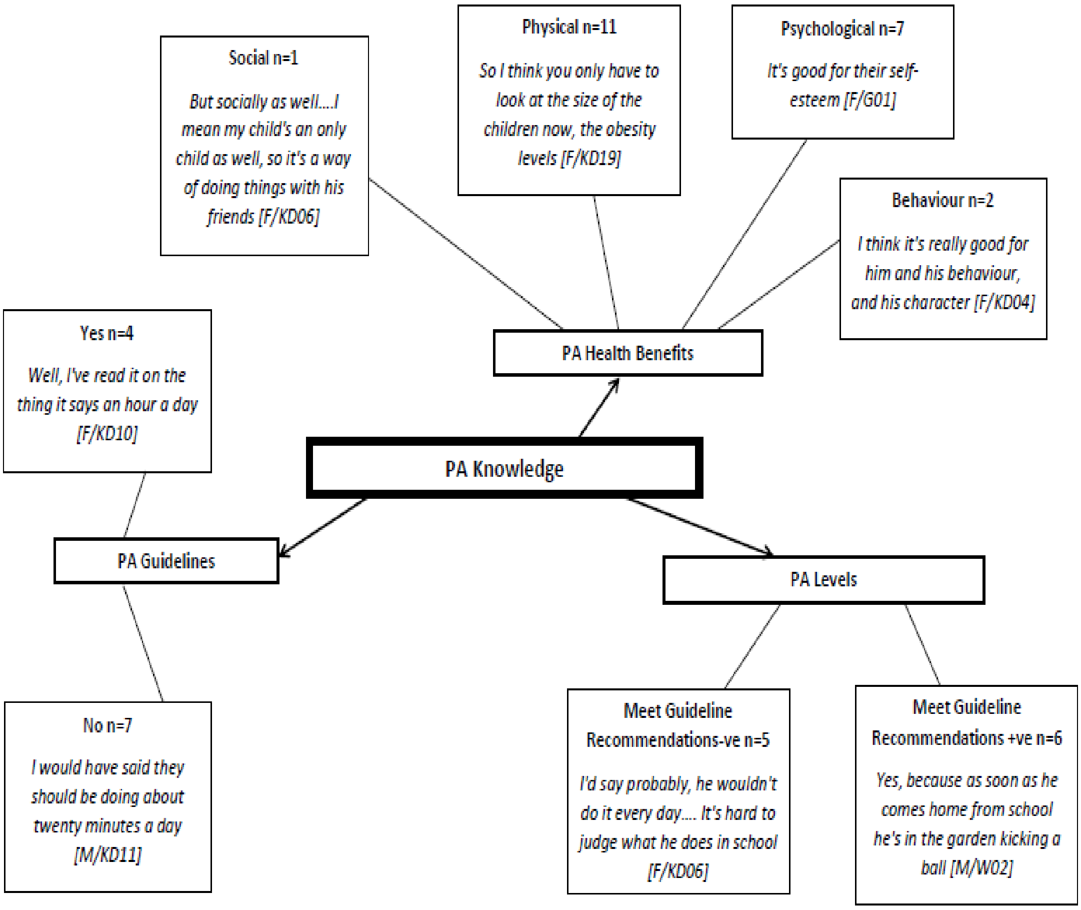



Figure 7.1 Parental PA knowledge. +ve = positive. -ve = negative. M = Male. F = Female

Factors influencing PA intervention engagement are presented in Figure 7.2, with 3 primary themes: delivery, benefits and timing, and 10 secondary themes: content −ve (*n* = 6), family focussed (*n* = 4), tangible (*n* = 3), content +ve (*n* = 3), ideas and knowledge (*n* = 8), family-based time (*n* = 8), health improvement (*n* = 4), assessment/feedback (*n* = 3), logistics (*n* = 7) and season (*n* = 2). Positive and negative influences featured in intervention engagement secondary themes.

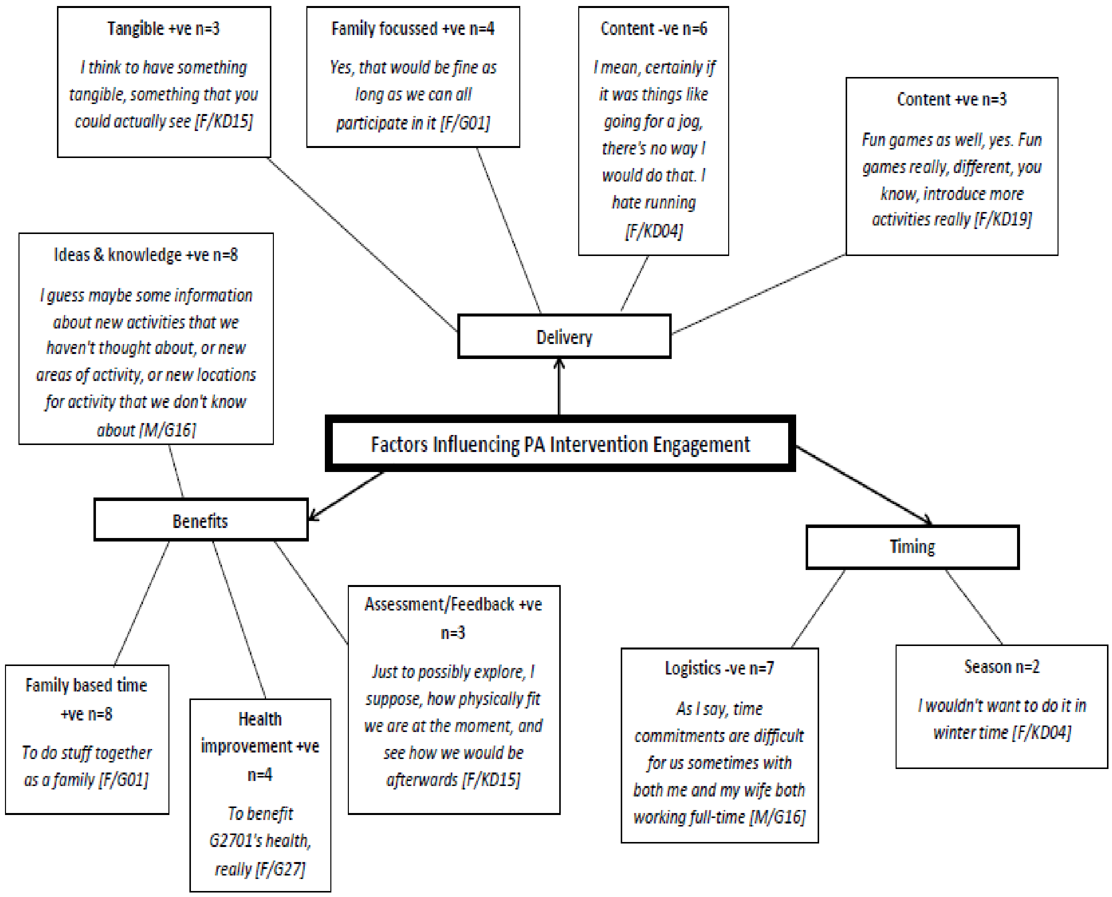



Figure 7.2 Factors influencing PA intervention engagement. +ve = positive. -ve = negative. M = Male. F = Female

Parents' perceived reinforcing factors to children's out-of-school PA are presented in Figure 7.3, with 6 primary themes: parental support, parental role models, parental restriction, parental time constraints, independent mobility and peers, and 18 secondary themes: parent attitudes (*n* = 2), verbal encouragement (*n* = 7), co-participation (*n* = 7), enrol (*n* = 2), parental role models (*n* = 2), parental time constraints (*n* = 7), road traffic fear (*n* = 4), proximity +ve (*n* = 2), neighbourhood connectedness (*n* = 3), social norm (*n* = 3), age (*n* = 7), stranger danger (*n* = 5), proximity (*n* = 2), peer co-participation +ve (*n* = 4), limited friends (*n* = 2), peer co-participation −ve (*n* = 2), sedentary behaviour +ve (*n* = 2) and sedentary behaviour –ve (*n* = 2). Positive and negative influences featured in both reinforcing primary and secondary themes.

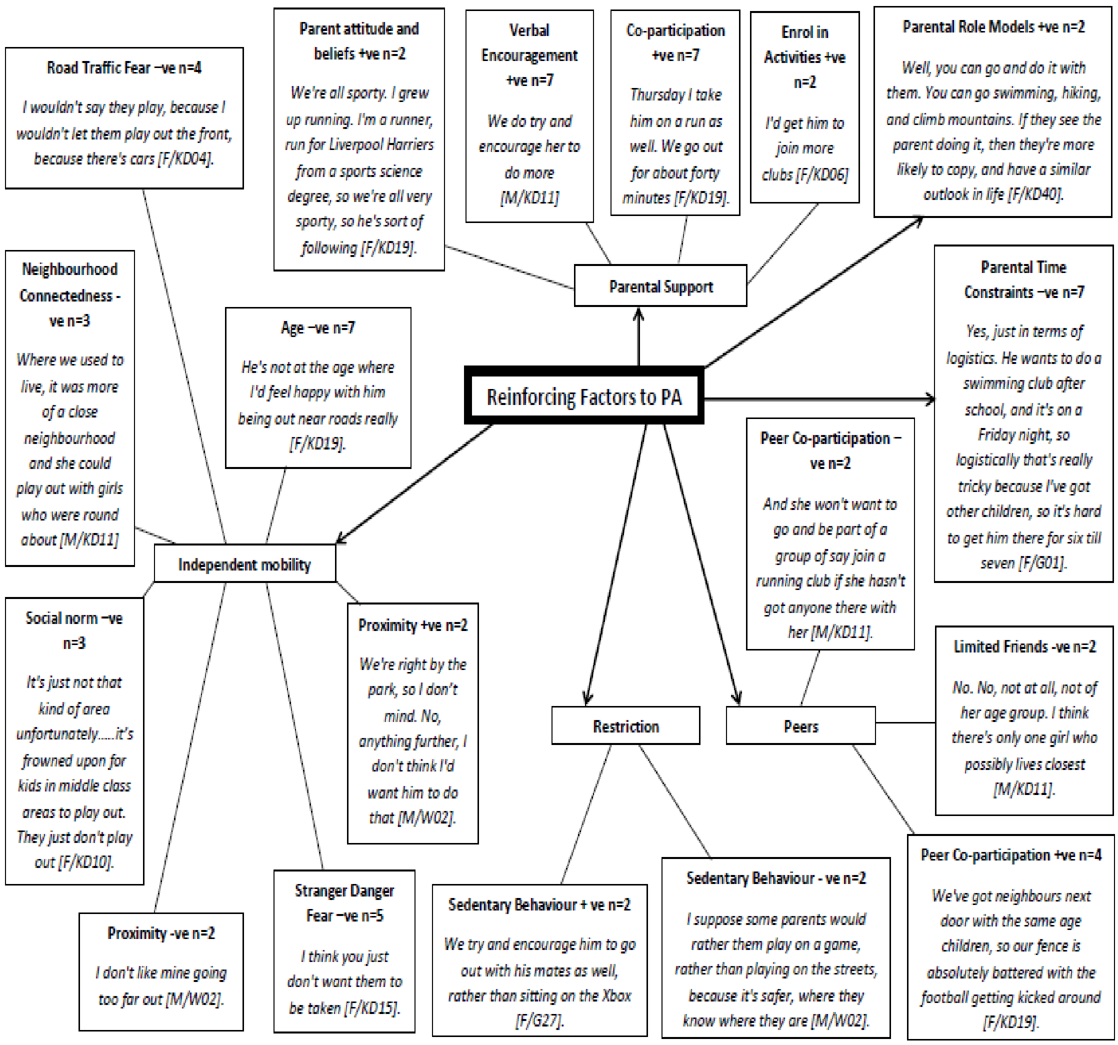



Figure 7.3 Parents' perceived reinforcing factors to children's out-of-school PA. +ve = positive. -ve = negative. M = Male. F = Female

Parents' perceived enabling factors to children's out-of-school PA are presented in Figure 7.4. There were five primary themes: environmental factors, ability, cost, sedentary devices and dog ownership, and nine secondary themes: weather ($n$ = 5), seasonality variation ($n$ = 5), proximity +ve ($n$ = 6), proximity −ve ($n$ = 2), provision +ve ($n$ = 6), garden +ve ($n$ = 6), garden −ve ($n$ = 3), illness and injury ($n$ = 2), and self-esteem ($n$ = 2). Positive and negative influences featured in both enabling primary and secondary themes.

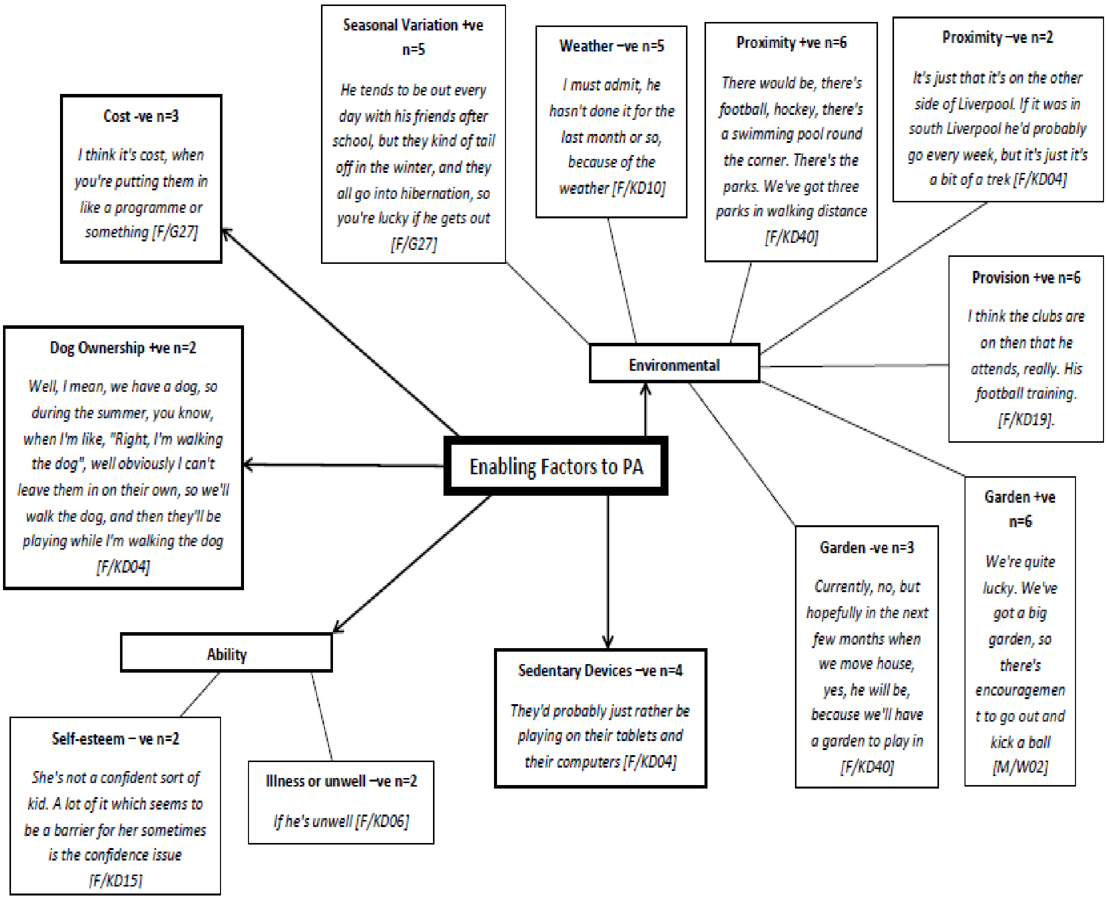



Figure 7.4 Parents' perceived enabling factors to children's out-of-school PA. +ve = positive. -ve = negative. M = Male. F = Female

## 7.4 Discussion

The purpose of this study was to increase understanding of parental PA knowledge and perceptions of children's out-of-school PA, as to inform design of out-of-school family-targeted intervention strategies. Identifying factors that facilitate and inhibit children's out-of-school PA is deemed to be central to intervention design, but research featuring the knowledge and perceptions of parents who serve as gatekeepers to children's out-of-school PA is presently limited. This study compliments chapter 6 and provides new insights and understanding of the mechanisms by which parents' perceptions towards the neighbourhood environment, and their own behaviours influence children's out-of-school PA. Most parents in this study were unaware of the UK PA guidelines for their child ($n$ = 7) and were unsure whether their child met the guidelines on a regular basis. Moreover, PA for many parents was associated with a healthy weight status, and the neighbourhood environment was perceived as unconducive to child outdoor play which consequently increased the attractiveness of adult supervised organised activities. Such findings have important implications for PA promotion messages and future out-of-school PA interventions targeting primary aged UK children and their families.

Box 7.1 Family case study for participant KD19

KD19's child is male, aged 11, categorised as healthy weight, scored highly on the PAQ-C (4.4/5.0) and CRF test (77 shuttles), lives in an affluent neighbourhood (IMD 29.1) distant from school (3.8 km), thereby reducing opportunities for active school travel. KD19 is categorised as a healthy weight, married with two other children, one boy and one girl, degree educated and reported regular PA (IPAQ score=3). She was acutely aware of the need for her son to accumulate at least 60 minutes of PA each day and was confident that he surpassed this benchmark habitually citing a broad range of organised, non-organised, school led, and family-based activities that he participates in throughout a typical week. Regular PA was attributed to both physical (e.g., healthy weight status) and psychological health (e.g., mental strength) outcomes and was deemed an essential part of creating an active lifestyle habit as to 'set a pattern for later on in life'. '*If you exercise as a child you set a pattern for later on in life'.* In addition, praising her son for his effort was considered crucial in improving his self-esteem and fostering a liking towards PA. '*I always say it, he's done amazing, so it's just giving positive feedback, even if he come last I'd say it, because……they feel so much happier in themselves, and I think it gives them a lift as well, and also it gives them a healthy outlook on life for the future as well'.*

Although PA participation challenges were acknowledged the necessity of prioritising and making sacrifices were considered more important. Family-based PA appeared a key part of family life. *We do participate in exercise together. 'As I said before, my husband takes them out cycling. And I take KD1902 out running. Even my six year-old little girl, after I've taken KD1902 out, she'll often ask, "Can I go round the block as well?", and she's got her little running trainers as well now…so we do do things together, and even the park, you know, we'll all go to the park, or we'll go and do a big walk. We go to Delamere Forest as well, take the children there walking, so yes'.*

The family home is located in a suburban neighbourhood with green space located very close by which the children occasionally utilise as a place for outdoor play. She expressed concerns and feelings of discomfort about 'letting' her son play outdoors and cycle on the nearby roads independent of her supervision, principally because of the danger posed by speeding motorised vehicles. *'The main reasons, I think people are just generally* *scared these days of letting them play out. I'm quite guilty of that'*. The large family garden therefore served as a valuable PA resource for her son and a setting for peer PA co-participation with neighbours. '*Well, he plays out in the garden. We've got a trampoline, and we've got neighbours next door with the same age children, so our fence is absolutely battered with the football getting kicked around and everything, but, do you know what? I'm not bothered'*.

KD19 exhumed a keenness and enthusiasm towards PA intervention engagement on the basis of educating and reinforcing positive attitudes towards PA in her children. She expressed the importance of ensuring the intervention content is fun, enjoyable and achievable for all involved as to accommodate for a broad range of fitness and ability levels and not simply 'put people off'. '*Make it fun, and achievable as well. Not too sort of difficult, because a lot of people are not very fit, and if it was really difficult to do, and unachievable, it would put people off straight away really'*. PA monitoring and goal setting were offered as behaviour change strategies to 'help' families increase their activity behaviour. *'Maybe put goals in it as well, short-term goals for them to achieve. Collect points per day, you know, and can you reach this many points at the end of the week? And, you know, put a step-ladder on how many. Where are you now? Where are you up to with our plan? Make the plan fun, rather than a chore'*.

### 7.4.1 Parental knowledge

All parents in this study associated children's engagement in PA with physical health benefits principally maintaining healthy weight status. Parental PA perceptions and knowledge may have important implications for PA promotional strategies and intervention recruitment. For example, parents who associate PA engagement with weight status and perceive their child to be of healthy weight status are unlikely to perceive their child to be insufficiently active or appreciate the relevance of public health messages advocating them to encourage their child to engage in additional PA (Corder et al. 2010). The findings presented here suggest that future PA promotion and intervention strategies may benefit from including information on the broad ranging health benefits of PA other than that of weight status and that have positive implications on other aspects of children's lives including cognition (Hillman, Erickson & Kramer, 2008), concentration (Silva et al. 2015), academic attainment (Singh et al. 2012) and self-esteem (Ahn & Fedewa, 2011). Endorsing PA as an essential component to positive child development and wellness may be a more powerful and resonating message to communicate when promoting child PA, particularly to parents (Burdette & Whitaker, 2005b).

Although all parents in this study demonstrated an awareness of the need for their child to engage in regular PA, fewer than half of the parents were specifically aware that the UK Government recommends children to accumulate at least one hour of MVPA each day. This is an important finding as parents who are unaware of PA guidelines are perhaps less likely to notice whether or not their child is sufficiently active which may in turn influence their decision to encourage them to engage in more PA (Sawyer et al. 2014) (Box 7.1).

Box 7.2 Family case study for participant KD40

KD40's child is male, aged 10, categorised as healthy weight, walks to school regularly (2.2 km travel distance), scored high on the PAQ-C (4.0/5.0) but relatively low on the CRF test (31 shuttles). They live in a highly affluent neighbourhood (IMD 18.6). KD40 is categorised as overweight, single with two other children, one boy and one girl, degree educated and reported moderate PA (IPAQ score=2). With regards to PA knowledge, perceived PA health benefits centred solely on physical health benefits principally 'fitness', and both knowledge of UK child PA guidelines and her child's PA levels were limited. The value of non-organised activities specifically active transport and outdoor play was however well recognised.

Although KD40 reported irregular engagement in PA she was extremely enthusiastic and keen to support her son's PA, and stressed the importance of not overexerting undue pressure on him to engage in activities that don't align to his interests. '*I'm not exactly regular, but I enjoy playing sport, and as long as he's enjoying it, then I'll support it, and I'm not one of these mothers that pushes him into be in the team to do this, and the team to do that. So I mean, if he wants to do it, and then he very happily just plays football on his own'.* Perceived behaviour change strategies to increase children's activity levels centred on parent-child PA and parents acting as positive role models through leading an active lifestyle. '*Because if they see the parent doing it, then they're more likely to copy, and have a similar outlook in life'.*

KD40 does not have a family garden but lives close to several public parks and a range of recreational facilities. Despite the low prevalence of child outdoor play in KD40's neighbourhood, she was enthusiastic about her children playing outdoors and visiting nearby parks independent of her supervision. KD40 believed the health benefits of outdoor play outweigh the safety risks and cited ‘over-protective parents’ as a key contributing factor to the dearth of children playing outdoors regularly in her neighbourhood. ‘*I personally think they should be playing out. Well, my kids will ride their bikes round where I live, and I'm happy for them to do that. I don't follow them. They ride round the block. I'm happy for them to go to the local park, just the two of them. So I personally believe that them being out and about is much better for them than being stuck at home but safe’.*

Family-based PA intervention was attractive to KD40 on the basis that it would provide an opportunity to spend increased time together as a family engaging in activities conducive to the health of the whole family. The opportunity to learn new information and ways in which the family can be active together to reduce the dependency on structured and organised provision was also considered an important motive for engagement. *‘You know, you don't actually have to go and get in the swimming pool or go to a tennis court. You can just do, or if you're out and about, you can just go, "Oh yes, let's play that game that is in that pack", or whatever’.* Barriers surrounding the timing of delivery were raised in response to KD40’s single parent status. ‘*It would only be if they did like an activity where you've got together, and it was on the time I didn't have the children….well, more that my children would be elsewhere, and their father can't get them there’.* KD40 suggested that rather than relying on information and flyers to recruit families for research studies, generating enthusiasm in children so that they have a keen interest in participating in the study may encourage parents to consent to participating on the basis of pleasing their child. *‘Well, yes, get somebody in with the kids in school, and get them on board with the activity, and then they're going home talking about it, rather than just taking home a leaflet. When the kids talk about stuff, that's when you start thinking, "Oh yes, we could do that"’.*

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Only half of parents in this study were confident that their child met the recommended PA guidelines daily, with PA undertaken during the school day confusing many parents’ judgement as to whether their child consistently achieves the daily PA target. Many of the children in this study (63.6%) travelled to school actively but very few parents ($n$ = 2) referred to this. Parents perceived their child to be most active after-school rather than other periods of the week as this was essentially when greater structured activity and sports club provision was available. Parents’ principally recalled children’s engagement in sport and organised activities, mainly team sports (i.e., football) ($n$ = 9), but also individual sports such as swimming and cross-country ($n$ = 6). The finding that children's out-of-school PA is principally comprised of sport and organised activities supports prior research (Skar & Krogh, 2009). Parents in this study were able to offer some insight into why this may be suggesting that structured and organised activities are a 'safer' alternative compared to outdoor play.

Children's engagement in structured activity created logistical challenges for families and due to parental time constraints restricted children's regular participation. 'Fitting' children's structured activities into the family schedule was particularly challenging for families comprising several children and two working parents. The financial cost of structured PA served as another participation barrier to out-of-school PA. Although sport participation offers physical and psychosocial health benefits to children (Eime et al. 2013), sport participation alone contributes a comparatively small proportion to children's overall PA (Payne, Townsend & Foster, 2013). There is therefore a need to develop intervention strategies that engage children in other forms of PA such as active transportation and outdoor play.

### 7.4.2 Out-of-school facilitators and barriers

Parents in this study considered themselves as important influences on their children's PA. Although verbal encouragement was the most consistently reported form of PA support, parents also recalled experiences of engaging in PA with their children, acting as PA role models and exhibiting positive attitudes towards PA, all of which are consistent correlates of child PA (Beets, Cardinal & Alderman, 2010; Mitchell et al. 2012). There was a consensus among parents that engaging in PA with their child presents the most promising way of increasing their child's PA by way of reinforcing an active lifestyle. Children also cited parent–child co-participation as a key motivator for out-of-school PA in Chapter 6. The weekend period may be the most salient time to encourage PA between parents and children given the decline in children's activity levels and the shortage of structured PA opportunities during non-weekdays (Brooke et al. 2014; Eyre et al. 2014). Interestingly, some parents expressed a keenness to engage in more frequent family-orientated activities with their children instead of simply watching their child participate in structured forms of PA, but stated that they were unaware of available provision or structured activities that allow children and parents to exercise together. As noted earlier, PA provision was solely linked to organised provision in this study. Outdoor recreational provision such as public parks can play an important role in facilitating family-based PA (i.e., play and leisure) (Cohen et al. 2007). Since park use was largely underreported in this study there may be strong potential for public parks to enhance family-based PA levels.

Parental safety concerns were the most consistent barrier to children's out-of-school PA. Almost all parents perceived the neighbourhood environment as unconducive to their child's outdoor play, with many considering the risks posed by the social and built environment surpassing the health benefits of playing outdoors. This study extends the qualitative literature on children's independent mobility by offering insight into neighbourhood environment norms and community influences. Outdoor play was uncommon in almost all neighbourhoods in this study, and according to some parents, 'letting' children play outdoors was considered socially unacceptable among neighbourhood residents. The rarity of children playing outdoors unsupervised is likely to normalise supervised indoor play creating negative neighbourhood norms surrounding children's independent play outdoors, whereas the presence of other children playing outdoors will likely ease parents' safety concerns due to children not being alone (i.e., safety in numbers) (Holt et al. 2015). Moreover, the absence of neighbourhood social cohesion was seen as another barrier to affording children independent mobility. One parent (F/KD10) cited not knowing many neighbours in the neighbourhood despite living there for a relatively long time, and another (M/KD11) reported living in an unclose neighbourhood. This finding complements previous quantitative research that found parents who perceived a high level of neighbourhood social cohesion were less fearful of their child playing outdoors and more willing to let them travel further away from home unsupervised (Schoeppe et al. 2015) (Box 7.2).

Consistent with previous studies (Carver et al. 2008; Lee et al. 2015) parental safety concerns regarding children's outdoor play were principally driven by fears regarding stranger danger and traffic volume. Age played a key role in parents' decision to afford children autonomy over their outdoor play. Parents indicated that the end of primary school is a period when they start to afford their children independence to play outdoors unsupervised. Parents may become less worried about children's safety as they age due to increases in motor and traffic awareness skills (D'Haese et al. 2015a). Alternatively, since outdoor play was considered unacceptable in some neighbourhoods in this study such an age could be socially driven. For example, affording children outdoor license prior to this age may be viewed in certain communities as 'bad parenting'. Further research is warranted to better understanding the intertwined relationship between perceived parental fear, child age and neighbourhood social norms.

For children who were restricted from playing outdoors the family garden appeared to be an important resource for their PA, especially among families with large gardens (Box 7.1). The availability and proximity of public open spaces and recreational provision is consistently associated with child PA (Dunton et al. 2014; Sanders et al. 2015). Parents in this study considered there to be a high level of provision in their surrounding neighbourhood, suggesting that the challenge to increasing children's PA is not providing more parks and facilities but rather providing conditions that foster the use of existing resources.

Screen time was another barrier to children's out-of-school PA. Consistent with prior research (Bentley et al. 2012), parents suggested that children become attached to their console games and sometimes have a greater preference for video games rather than more active pursuits such as playing outdoors with friends. However, it is important to note that for some parents, computer gaming and TV viewing may serve as an attractive alternative to outdoor play in order to be confident of their child's whereabouts, particularly during the winter months when day light hours are reduced and perceived safety risks are heightened. Given that parental sedentary behaviour restriction had a positive effect on children's PA in this study with children opting to play outdoors in the garden or with friends, educating parents to encourage children to play outdoors more regularly with friends rather than confining them to the family home could be a low-cost and effective means of increasing PA and reducing sedentary time during out-of-school hours. In this case, advocating play and emphasizing outcomes, such as positive social interaction and emotional well-being rather than obesity prevention, may resonate more strongly with parents when suggesting that their child be more active, particularly outdoors (Burdette & Whitaker, 2005b).

### 7.4.3 Intervention design

On the whole, most parents (*n* = 9) in this study thought that engaging in a family-based PA intervention programme would have positive implications for their family, and perceived factors influencing their engagement were generally consistent with previous research (Bentley et al. 2012; Jago et al. 2012). Two parents considered both their children and family as very active by definition of regular engagement in structured PA provision, and therefore viewed themselves as not the intended target audience. This finding demonstrates the importance of consulting with parents prior to familial intervention to build trust and communicate the relevance of programmes for families as to aid subsequent intervention recruitment and engagement.

A common strategy used in family-based PA interventions has been to deliver activity sessions or workshops to families and examine whether PA and health-related outcomes improve post intervention (Milton et al. 2011; Monteiro, Jancey & Howat, 2014). Parental concerns regarding intervention engagement centred principally on practical barriers (i.e., transport, work schedules and competing demands on family time) and timing of delivery, suggesting that this may not be the most effective strategy to foster familial interest or engagement. Parents may instead prefer more flexible educational methods, such as online materials or activities that can be completed at home or in the neighbourhood with their children.

Parents in this study demonstrated intent to increase and maintain family PA but reported difficulties linking their intentions with action. Rhodes, Naylor & McKay (2010) found that increases in parent planning and regulatory capabilities led to subsequent increases in PA. Future interventions should build on this research by supporting parents and families to link their intentions with PA support and family PA. Moreover, family-based intervention was viewed by most parents (*n* = 8) as an important opportunity to spend additional time together as a family and receive feedback on current activity behaviours. Remotely delivered interventions comprising family PA goal tasks that children and parents complete together and receive feedback on may serve as a more practical and engaging method for families compared to traditional educational workshop approaches (Cohen et al. 2013; West et al. 2010). Activity monitors such as pedometers provide feedback reflecting individual activity behaviour and facilitate self-monitoring and personalised goal setting. In a recent family-based intervention study, both maternal and paternal increases in step counts significantly predicted an increase in child step counts (Holm et al. 2012). Increasing child and parent self-efficacy by providing feedback about PA may facilitate and improve PA among families (Horne et al. 2009). The findings presented here have uncovered new insights on potential important and relevant content to inform future out-of-school family-based interventions.

This is the first study to triangulate quantitative and qualitative data sources to explore parental perceptions of children's out-of-school PA and family-based intervention design, with distinction between socio-demographic and neighbourhood environmental characteristics. In doing so, the study extends beyond traditional methodologies and offers comprehensive alternative perspectives on parental PA perceptions, knowledge and intervention design. The research presented here also builds on previous qualitative PA research by considering individual, social and environmental factors, including the influence of independent mobility, which provides new insights into an understudied area. Methodological strengths include the pen profile analyses that provide an accurate and detailed concensus, rather than over-representing minority parental views, and the supplementary verbatim quotations verified parental responses. Furthermore, the triangulation consensus of data between research team and methods provided credibility, transferability and dependability. Limitations of this study relate to a small homogenous sample of parents of children living in affluent neighbourhoods of a highly deprived English City. Therefore, generalising the results to younger children and locations should be done so with caution. Although opportunities to probe responses can be reduced during telephone interviews, they are a more convenient approach for parents compared to face-to-face interviews, which may enhance study recruitment. Further, unlike focus groups their design facilitates more honest and open discussion around personal views and familial topics, which, as seen in this study, are important contributory factors to intervention familial design (Novick, 2008).

## 7.5 Conclusion

The findings of this study could be used to design interventions that seek to encourage parents to be more active with their children. Given the apparent family differences in attitudes highlighted in the family case studies, it may be beneficial for future interventions and public health strategies promoting family-focussed PA to allow scope for family-specific activity preference. In conclusion, formative mixed methods research facilitates intervention content to be aligned with family-specific perceptions and needs, and offers opportunities to communicate the relevance of programmes to parents. This may aid subsequent intervention recruitment and engagement.

**Thesis study map**

| **Study** | **Objectives and key findings** |
|---|---|
| Study 1: Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. | **Objectives:**<br><br>(1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation.<br><br>(2) To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.<br><br>**Key findings:**<br><br>• High deprivation children had higher BMI z-scores and waist circumference and lower CRF compared to medium-to-high deprivation children.<br>• High deprivation children lived in less walkable neighbourhoods and were less likely to have access to a garden than medium-to-high deprivation children.<br>• PA was inversely associated with bedroom media and positively associated with independent mobility.<br>• Independent mobility was inversely associated with crime safety and neighbourhood aesthetics. |
| Study 2. Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week. | **Objectives:**<br><br>(1) To assess children's physical activity levels derived from wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data. |

| | |
|---|---|
| | (2) To examine the comparability of physical activity levels between the two devices throughout the segmented week.<br><br>**Key findings:**<br><br>• Children’s raw PA levels were lowest on weekend days.<br>• Wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ derived raw PA levels are not comparable in children.<br>• The largest differences in GAwrist and AGhip derived raw PA were observed at the lowest intensity and during school hours. |
| Study 3. Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity. | **Objectives:**<br><br>(1) To use a novel combination of qualitative techniques to explore children’s current views, experiences and perceptions of out-of-school physical activity as well as offering formative opinion about future intervention design.<br><br>**Key findings:**<br><br>• Parents served as both enablers (i.e., encouragement) and barriers (i.e., restricting participation) to children’s PA.<br>• Involvement of parents and the whole family is a strategy that could be significant to increase children's PA levels.<br>• WDST is an inclusive, interactive and child-centred methodology which facilitates the exploration of a wide range of topics and enhances data credibility. |
| Study 4. Parental perceptions on children’s out-of-school | **Objectives:** |

| | |
|---|---|
| physical activity and family-based physical activity. | (1) To explore parents' PA knowledge and perceptions of children’s out-of-school PA to formatively contribute to a family-based intervention design.<br><br>**Key findings:**<br><br>• Few children played outdoors.<br>• A range of social and built environmental factors influence parents’ decision making to allow their children to play outdoors.<br>• Perceived PA social norms, resources and opportunities, and neighbourhood environmental barriers influence children’s PA levels and activity mode.<br>• Consulting with parents in a formative sense prior to familial PA intervention may aid subsequent intervention recruitment and engagement. |
| Study 5. Context matters! Sources of variability in weekend physical activity among families: A repeated measures study. | **Objectives:**<br>(1) To investigate the stability of weekend MVPA among target children, siblings, and parents using repeated measures raw accelerometer data.<br>(2) To offer contextual insight into the characteristics of weekend PA amongst one representative low active family and one high active family. |

# Chapter 8

# Study 5:

# Context matters! Sources of variability in weekend physical activity among families: A repeated measures study.

The main outcomes of this study have been published in *BMC Public Health*: Noonan, R. J., Fairclough, S. J., Knowles, Z. R., & Boddy, L. M. (2017). Context matters! Sources of variability in weekend physical activity among families: A repeated measures study. *BMC Public Health*, 17:330. The published article can be found in Appendix A.

## 8.1 Introduction

Chapter 5 identified the weekend as a period of low MVPA but provided limited contextual understanding of the activities children undertake on weekend days. Moreover, consistent with previous studies (Aadland & Johannessen, 2015; Addy et al. 2014; Basterfield et al. 2011; Hislop et al. 2014; Mitchell et al. 2015; Ojiambo et al. 2011; Rich et al. 2013), Chapter 5 measured PA once over a 7-day period encompassing weekdays and weekend days. Consequently, how representative this one-off measurement of weekend PA is of typical weekend PA behaviour remains unknown.

Children's PA comprises a broad range of structured (e.g., organised sport) and unstructured activities (e.g., active travel, outdoor play) that take place in a variety of settings (Payne et al. 2013; Pearce et al. 2013). The school setting provides a range of PA opportunities for children and contributes a significant proportion of their daily PA (Fairclough et al. 2012; Guinhouya et al. 2009). These school-based PA opportunities are inclusive to all, as they form part of the school curriculum (e.g., physical education), discretionary time in school (e.g., recess play), and after-school provision (e.g., organised after-school activities) during the school week. In contrast, opportunities for PA on weekend days are strongly influenced by parental encouragement (e.g., positive verbal reinforcement) and support (e.g., payment of club subscriptions, transport to and from provision) (Chapter 6 and 7; McMinn et al. 2013), as well as constraints on individual choice (e.g., access to garden/yard) (Chapter 4; Oliver et al. 2016; Remmers et al. 2014a). Given that children also experience less structure and routine, and thus more behavioural choice on weekend days compared to weekdays, it is likely that their PA levels will vary considerably between weekends (Mattocks et al. 2007a; Wickel & Welk, 2010). However, further research is needed to specifically examine the variability of weekend PA from repeated measurements.

The weekend is an important time period for PA promotion. Firstly, children tend to accumulate the least amount of daily MVPA on weekend days (Brooke et al. 2014). Secondly, during the school term, weekends offer children the most discretionary time for leisure activity, and opportunities for the whole family to be physically active can be implemented more easily on weekends (Zahra, Sebire & Jago, 2015). Family involvement is an essential component of effective PA interventions in children (Brown et al. 2016; Davison et al. 2013; Kipping et al. 2014). Understanding the PA patterns of families is necessary for designing effective family-based PA interventions. However, little is known about the PA behaviours and habitual routines of families on weekends. To date, family-focused research has mainly been conducted using qualitative methodologies and has engaged mostly with parents exploring their assessment of children's PA (De Lepeleere et al. 2012; Zahra, Sebire & Jago, 2015), and family-based PA interventions (Bentley et al. 2012; Brown et al. 2015; Davison et al. 2013; Jago et al. 2012). However, none of these studies have involved all household family members as participants, or included objective assessments of PA.

The inclusion of whole families comprising of target children, parents, and siblings in the same study as participants offers an original way in which to explore the characteristics of family unit weekend PA. Further understanding into the characteristics of weekend PA among different family units may help inform the design of family-focused PA interventions. This study, therefore, assessed 'target' children's PA, and their siblings and parents PA over 8 weekends using accelerometry and PA diaries. The aims of the study were twofold: 1. To investigate the stability of weekend MVPA among target children, siblings, and parents using repeated measures raw accelerometer data, and 2. To offer contextual insight into the characteristics of weekend PA amongst one representative low active family and one high active family.

## 8.2 Study specific methods

### 8.2.1 Participants and setting

Families including a 'target' child aged 9-11 years, their primary caregiver(s) (herein referred to as parents) and siblings aged 6-8 years were recruited through primary schools in Liverpool, UK. Three primary schools located in areas representing varying socioeconomic status based on the UK Indices of Multiple Deprivation (IMD) (SES; IMD = 12.0 (UK tertile 2), IMD = 38.4 (UK tertile 5), and IMD = 43.6 (UK tertile 5)) were approached as convenience samples and agreed to participate in the study. The selected schools had participated in each of the previous study chapters. Information flyers, written study information and a questionnaire were issued to all Year 5 and 6 children ($n$ = 210) in participating schools to take home for their parent to complete and return upon completion. All school aged siblings (>4 years and <18 years) and parents living in the same household were invited to take part. Minimum inclusion criteria for a family required one child participant aged 9-11 years and at least one parent participant. Completed informed parental consent and child assent were returned from seven families. The researcher contacted consenting parents via SMS to arrange a suitable time to visit all family members at their home address. The study received institutional ethics approval (reference number: 15/SPS/023) and data collection took place between June 2015 and April 2016. Each family received a £50 high street shopping voucher after data collection in return for their participation.

### 8.2.2 Measures and procedures

#### 8.2.2.1 Socioeconomic status

Area-level SES was calculated using the 2015 IMD (Department for Communities and Local Government, 2015), as described in Section 3.7 of General methods Chapter 3. Individual level SES was assessed using the highest level of education for each family. Responses included; high school, post-16 college, university, higher degree (Corder et al. 2016).

#### 8.2.2.2 Anthropometrics and maturation

All anthropometric measures were taken at the home addresses of participating families. Child stature, sitting stature, body mass, BMI, BMI z-scores, and waist circumference were taken by the researcher as described in General methods, Chapter 3, Section 3.3. Somatic maturation was calculated using the Mirwald equations (Mirwald et al. 2002) as described in General methods, Chapter 3, Section 3.4. Parent stature and body mass were measured by the researcher as described in General methods, Chapter 3, Section 3.3. BMI was calculated from stature and body mass ($kg/m^2$) and BMI cut-points were used to classify parent weight status (World Health Organization, 2000).

### 8.2.2.3 Habitual physical activity

PA was assessed using the ActiGraph GT9X accelerometer which features ActiGraph's validated tri-axial accelerometer and data filtering technology (GT9X, theActiGraph.com, FL, USA) (Hanggia, Phillips & Rowlands, 2013; Robusto & Trost, 2012). The GT9X model was selected because it measures raw accelerations and is worn on the wrist, which is associated with improved device wear (Fairclough et al. 2016). Participants wore the accelerometer on their left wrist during waking hours for two weekend days. They were instructed to only remove the monitor during water-based activities and when sleeping. Verbal and written instructions for care and placement of the monitor were given to participants by the researcher. After the two measurement days accelerometers were collected from home addresses, the data downloaded, and then returned to participants on the subsequent Friday to wear again on weekend days. This process was repeated on four consecutive occasions in one season and on a further four consecutive occasions in the subsequent season, resulting in a total of 16 weekend measurement days per participant. Four families completed measures between June and December 2015 and three families completed measures between October 2015 and April 2016. The accelerometers were set to record data at a frequency of 30 Hz, and were marked with separate color-coded stickers for parents and children to avoid any mistaken cross usage. Data collection took place during the regular school term so activities were representative of usual free-living activities.

ActiGraph data were downloaded using ActiLife v. 6.11.4 (ActiGraph, Pensacola, FL), saved in raw format as GT9X files, and subsequently converted to CSV format to facilitate raw data processing. Raw data files were processed in R (http://cran.r-project.org) using the GGIR package (version 1.2-0) which converted raw triaxial acceleration values into one omnidirectional measure of acceleration, termed the signal vector magnitude (SVM). SVM was calculated from raw accelerations from the three axes minus 1g which represents the value of gravity (i.e., SVM = √(x2 + y2 + z2) – 1), after which negative values were rounded to zero. This metric is referred to as the Euclidean norm minus one (ENMO) (van Hees et al. 2013). Raw data were further reduced by calculating the average SVM values per 5-s epoch expressed in mg over each of the 16 monitored days.

ActiGraph raw data wear times were estimated on the basis of the standard deviation and value range of each axis, calculated for 60 minute moving windows with 15 min increments (van Hees et al. 2013). A time window was classified as non-wear time if, for at least 2 out of the 3 axes, the standard deviation was less than 13.0 *mg* or if the value range was less than 50 *mg* (van Hees et al. 2013). A valid day was classified as 10 hours or more of accelerometer wear (Mattocks et al. 2008). Participants without 1 valid weekend day each weekend were coded as missing. MVPA was the primary raw acceleration outcome variable. Wrist-worn specific ActiGraph equations provided by Hildebrand et al. (2014) were used to classify MVPA. The Hildebrand equations were solved for 3 METs resulting in MPVA cut-points of 201.4 *mg* and 100.6 *mg* for children and parents, respectively.

#### 8.2.2.4 Physical activity diary

Participants were provided with a calendar format paper-based diary to manually record their PA at the end of each day on each of the 8 weekends. The diary contained separate columns for participants to record the mode (e.g., football, walking) and duration of activity (in minutes), start and end times, location of activity and with whom the activity was undertaken (e.g., on my own, with friend, with brother/sister). Verbal instructions were given to participants by the researcher at the first home visit, and an example of a completed entry was provided on the diary to maximise the quality of information provided. Diaries were collected from home addresses by the researcher after each measurement period. Deductive content analysis was used to explore the diary data (Braun & Clarke, 2006). Diary responses were categorised in relation to two higher order themes (i.e., mode of activity and with whom the activity was undertaken), and six lower order themes including unstructured PA (e.g., walking, outdoor play), structured PA (e.g., gym based exercise and activities involving financial cost), club-based/organised PA (e.g., football club and other sporting activities), alone, friend and family (e.g., parent/sibling)) to align with the study objectives. Each recorded entry produced two lower order themes. For example, 'I played out with friends' would require marks for unstructured PA and friend. Individual participant responses were summed to produce frequency counts for each lower order theme and then combined to produce an overall frequency count for target children, siblings, mothers and fathers. These were then expressed as a percentage of total number of entries for target children, siblings, mothers and fathers. To ensure accuracy and allow for alternative interpretations of the data, the diaries were independently reviewed by two members of the research team and were then cross-examined against the data in reverse, from the frequency counts to the PA diary data sheets. This process was repeated until a 90% agreement level had been reached by the group.

### 8.2.3 Analyses

#### 8.2.3.1 Study aim 1

Participant characteristics were analysed descriptively. Variance components in linear mixed models were used to calculate mean MVPA for each weekend, and sources of variability in weekend MVPA for target children (*n* = 7), siblings (*n* = 6), mothers (*n* = 7) and fathers (*n* = 5). Weekend specific MVPA means were calculated by fitting MVPA as the dependent variable, weekend of measurement (1–8) as a fixed effect, and participant (identification number) as a random effect. Weekend of measurement was nested within participants to take the clustering effect of each participant into account. Preliminary analyses confirmed that there were no systematic differences in MVPA or accelerometer wear time due to seasonal/weather variables or accelerometer wear time, therefore these variables were not included as covariates in the variance components models. Variance components were estimated via restricted maximum likelihood estimates using a compound symmetric covariance structure. Variance components were estimated for participant (inter-individual), weekend of measurement, and residual error (intra-individual). Inter-individual variation represents true differences between participants. Weekend variation represents mean differences between weekends. Intra-individual variability represents variation in PA from weekend-to-weekend within participants. The variance components were expressed as a percentage of total variance. To assess the stability of MVPA across weekends, intraclass correlation coefficients were calculated from the proportion of total variance accounted for by inter-individual sources, and used as a measure of reliability (R). Analyses were conducted using IBM SPSS Statistics v.23 (SPSS Inc., Chicago, IL, USA). Statistical significance was set at 0.05.

#### 8.2.3.2 Study aim 2

To provide contextual insight into the characteristics of weekend PA among families, accelerometer, diary, and demographic data for one low active and one high active family were used to produce descriptive case studies. The case study families were purposively selected based on their PA profile from study aim 1. Prior to writing the case studies, the quantitative data were assessed by the research team and consensus was reached that the selected families would allow for the study aims to be achieved. The case studies offer insight into the physical activities that low and high active families undertake on weekend days and demonstrate how this can influence the stability of their weekend PA levels over time. Demographic information in conjunction with accelerometer and PA diary data for contrasting family structures are presented alongside the variance components data (Box 8.1 and 8.2). Pseudonyms were assigned to families and individual case study participants to assure anonymity.

## 8.3 Results

### 8.3.1 Study aim 1

A total of 25 individual participants from 7 families participated. This included 7 'target' children (boys $n$ = 4; mean age 10.4 years (SD = 0.6)), 6 other children (siblings; boys $n$ = 4, 7.2 years (SD = 0.7)) and 12 adults (mothers $n$ = 7; 40.3 years (SD = 5.2); fathers $n$ = 5, 41.7 years (SD = 2.8)). Seven weekends were excluded from the analyses for target children and mothers, and 4 weekends were excluded for siblings due to insufficient accelerometer wear time. Therefore, out of a possible 56 weekends, there were 49 weekends of data for target children and mothers. Less data were available for siblings (44 weekends) and fathers (40 weekends). Mean daily accelerometer wear time across weekends was high ranging from 14.2 hours (mothers) to 13.4 hours (siblings). Descriptive characteristics of the participants are presented in Table 8.1. With regards to target children, girls were older, heavier and closer to peak height velocity than boys, and had higher BMI, BMI z-scores and IMD scores. Stature and waist circumference were greatest among boys. All target children were classified as healthy weight. With regards to siblings, girls were older, taller and closer to peak height velocity than boys, but boys had higher body mass, BMI and waist circumference than girls. Most siblings were healthy weight (83%). Seventy-one percent of mothers and sixty percent of fathers were healthy weight. Mean BMIs for mothers and fathers were 24.5 (SD = 6.3) and 26.5 (SD = 4.8), respectively.

Table 8.1 Characteristics of participants

| Variable | All ($n$ = 7) Mean ± SD or % | Boy ($n$ = 4) Mean ± SD or % | Girl ($n$ = 3) Mean ± SD or % |
|---|---|---|---|
| *Target children* | | | |
| Age (years) | 10.4 ± 0.6 | 10.3 ± 0.8 | 10.6 ± 0.2 |
| Stature (cm) | 146.4 ± 5.1 | 148.6 ± 5.2 | 143.5 ± 4.0 |
| Body mass (kg) | 34.8 ± 4.9 | 34.1 ± 5.6 | 35.7 ± 4.7 |
| BMI (kg/m²) | 16.2 ± 1.8 | 15.4 ± 1.6 | 17.3 ± 1.7 |
| BMI Z-score | -0.6 ± 1.0 | -1.0 ± 1.1 | -0.0 ± 0.6 |
| Weight status (%) | | | |
| Normal weight | 100 | 100 | 100 |
| Waist circumference (cm) | 63.7 ± 4.7 | 66.0 ± 4.5 | 60.6 ± 3.3 |
| Maturity offset (years) | -2.2 ± 1.0 | -3.0 ± 0.5 | -1.3 ± 0.3 |
| MVPA (mins·day⁻¹) | 63.7 ± 33.4 | 72.5 ± 43.6 | 52.0 ± 11.9 |
| *Siblings* | All ($n$ = 6) | Boy ($n$ = 4) | Girl ($n$ = 2) |
| Age (years) | 7.2 ± 0.7 | 7.2 ± 0.7 | 7.4 ± 1.0 |
| Stature (cm) | 127.2 ± 5.4 | 126.3 ± 6.7 | 129.0 ± 1.5 |
| Body mass (kg) | 24.3 ± 5.2 | 24.8 ± 6.6 | 23.2 ± 1.8 |
| BMI (kg/m²) | 14.9 ± 2.1 | 15.4 ± 2.5 | 13.9 ± 0.8 |
| BMI Z-score | -0.9 ± 1.7 | -0.8 ± 2.1 | -1.3 ± 0.6 |
| Weight status (%) | | | |
| Normal weight | 83.3 | 75.0 | 100.0 |
| Overweight | 16.7 | 25.0 | 0.0 |
| Waist circumference (cm) | 59.4 ± 7.7 | 60.5 ± 9.7 | 57.2 ± 1.0 |
| Maturity offset (years) | -4.5 ± 0.8 | -4.9 ± 0.5 | -3.7 ± 0.6 |
| MVPA (mins·day⁻¹) | 119.1 ± 41.9 | 124.6 ± 52.5 | 108.1 ± 12.7 |
| *Parent* | | Male ($n$ = 5) | Female ($n$ = 7) |
| Age (years) | | 41.7 ± 2.8 | 40.3 ± 5.2 |
| Stature (cm) | | 179.0 ± 9.8 | 164.2 ± 3.9 |
| Body mass (kg) | | 84.2 ± 11.4 | 65.8 ± 16.6 |
| BMI (kg/m²) | | 26.5 ± 4.8 | 24.5 ± 6.3 |
| Weight status (%) | | | |
| Normal weight | | 60.0 | 71.4 |
| Overweight | | 20.0 | 0.0 |
| Obese | | 20.0 | 28.6 |
| MVPA (mins·day⁻¹) | | 130.8 ± 56.2 | 171.5 ± 110.9 |

Mean weekend MVPA levels across weekends are presented in Figure 8.1. MVPA was higher in siblings compared to target children, and in fathers relative to mothers. There were no significant differences in MVPA between weekends for fathers and siblings respectively. Target children's and mothers' MVPA was higher on weekend 1 and 2 ($p$ < 0.05), and weekend 6 ($p$ < 0.01) and 7 ($p$ < 0.05), respectively.

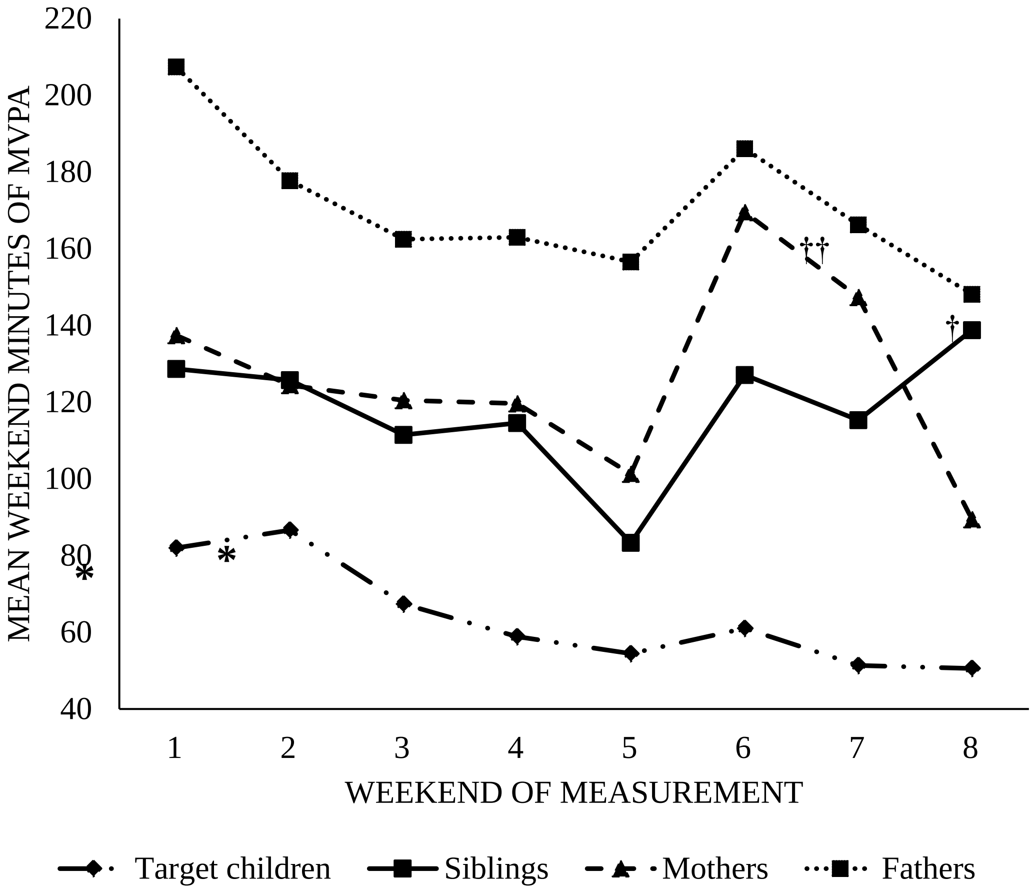


Figure 8.1 Mean MVPA in target children, siblings, mothers and fathers across measurement weekends. MVPA: moderate-to-vigorous physical activity. P-value was from linear mixed model comparing MVPA means across weekends, fitting participant as random effect. * Main effect for weekends in target children (weekend 1 and weekend 2 vs. mean weekend, $p < 0.05$). † Main effect for weekends in mothers (weekend 7 vs weekend mean $p < 0.05$). ††Main effect for weekends in mothers (weekend 6 vs weekend mean $p < 0.01$).

Table 8.2 displays the sources of variance in MVPA among target children, siblings, mothers and fathers. There was a high degree of variability in target children's (ICC = 0.55), siblings' (ICC = 0.38), and mothers' MVPA across weekends (ICC = 0.58). Fathers' MVPA was more stable (ICC = 0.83). Total variance was highest in fathers followed by mothers, siblings, and then target children. Inter-individual variance was proportionally the largest source of total variance for target children, siblings, mothers, and fathers but varied considerably (83.1 – 35.1%). Inter-individual variability was highest in fathers and lowest in siblings. Weekend variance accounted for the second largest source of total variance (9.0 – 35.0%), followed by intra-individual variability (7.2 – 27.6%). Intra-individual variance was highest in siblings and lowest in fathers. In models fitted without nesting the weekend effect within participants, the weekend effect was minimal (< 5 percent of the total variance), and was instead absorbed in the within-participant variance (i.e., residual error). This signified heterogeneous MVPA patterns in the sample for weekend effects.

Table 8.2 Sources of variance in MVPA in target children, siblings, mothers and fathers.

| | MVPA | |
|---|---|---|
| Source of variance | Variance | % of total variance |
| *Target children* | | |
| Intra-individual | 183.7 | 10.8 |
| Weekend | 580.4 | 34.1 |
| Inter-individual | 939.7 | 55.2 |
| Total | 1703.8 | |
| *Siblings* | | |
| Intra-individual | 1086.4 | 27.6 |
| Weekend | 1350.7 | 34.3 |
| Inter-individual | 1496.7 | 38.1 |
| Total | 3933.8 | |
| *Mothers* | | |
| Intra-individual | 333.7 | 7.2 |
| Weekend | 1631.4 | 35.0 |
| Inter-individual | 2697.7 | 57.9 |
| Total | 4662.8 | |
| *Fathers* | | |
| Intra-individual | 1117.2 | 7.9 |
| Weekend | 1279.7 | 9.0 |
| Inter-individual | 11798.3 | 83.1 |
| Total | 14195.2 | |

MVPA: moderate-to-vigorous physical activity; Percentages may not add to 100% due to rounding.

Table 8.3 presents the PA diary data for target children, siblings, mothers and fathers. There were a combined total of 303 recorded entries for: primary children ($n$ = 83), siblings ($n$ = 95), mothers ($n$ = 73), and fathers ($n$ = 52). Target children's weekend PA time was mostly undertaken with friends (54.2%) and family members (45.8%), and was mainly unstructured in nature (63.9%). Only 4.8% of target children's weekend PA was undertaken alone. Siblings' weekend PA was more club-based (41.1%) compared to target children's (19.3%), and they spent no time alone (0.0%). Mothers' weekend PA was mostly unstructured (61.6%) and conducted with the family (49.3%) or alone (46.6%). Father's weekend PA was more structured and club-based (32% and 21.2%, respectively) than mothers (24.7% and 13.7%, respectively) and a greater proportion of fathers' weekend PA was conducted with friends (11.5%) compared to mothers (4.1%).

Table 8.3 Target children's, siblings', mothers' and fathers' weekend PA by mode and who they were with.

| | Mode (%) | | | Who with (%) | | |
|---|---|---|---|---|---|---|
| | Unstructured | Structured | Club/organised | Alone | Friend | Family |
| Target children (*n* = 83) | 63.9 | 16.9 | 19.3 | 4.8 | 54.2 | 45.8 |
| Siblings (*n* = 95) | 50.5 | 8.4 | 41.1 | 0.0 | 58.9 | 41.1 |
| Mothers (*n* = 68) | 61.6 | 24.7 | 13.7 | 46.6 | 4.1 | 49.3 |
| Fathers (*n* = 52) | 46.2 | 32.7 | 21.2 | 38.5 | 11.5 | 50.0 |

*n* = refers to number of entries

### 8.3.2 Study aim 2

The descriptive characteristics of families are presented in Table 8.4. The sample was all white British. The mean IMD score for the sample (26.0 (SD = 11.5)) was slightly higher than the English average (23.6; Department for Communities and Local Government. 2015). Over fifty percent of families were degree educated, and all mothers except one had a spouse or partner that was the children's other parent. All but one family had access to a self-contained garden/yard. Individual case studies for the Evans and Williams families are presented in boxes 8.1 and 8.2, respectively.

Table 8.4 Characteristics of families

| Family | IMD (tertile) | Parent education level | Marital status | Target child gender | Sibling gender | Garden/ yard |
|---|---|---|---|---|---|---|
| 1 | 36.6 (5) | high school | single, never married | Boy | Girl | No |
| 2 | 29.5 (4) | university | married | Girl | Boy | Yes |
| 3 | 42.4 (5) | post-16 college | married | Girl | N/A | Yes |
| 4 | 19.5 (3) | university | married | Girl | Boy | Yes |
| 5 | 17.2 (3) | higher degree | married | Boy | Boy | Yes |
| 6 | 9.5 (2) | university | married | Boy | Girl | Yes |
| 7 | 27.5 (4) | high school | married | Boy | Boy | Yes |

Box 8.1 Family case study for Evans family (Family 1)

The Evans family were of a lower SES than the study average (IMD 36.6 – quantile 5). They live in a terraced house located in an urban residential area. The family comprises of a mother and four children (Jamie, aged 10, Mia, aged 8, Liam aged 4 and Izzy aged 2). Miss Evans is healthy weight, unemployed, with high school education. Her MVPA across weekends was low but stable (Figure 8.3a) and was amassed through walking and household chores. The Evans children’s weekend PA was completely unstructured in nature. Outdoor play formed the basis of Jamie’s weekend PA. Jamie played outdoors with his friends in the neighbourhood streets and local public green spaces. His MVPA levels were low, and showed no apparent structure or routine across weekends (Figure 8.2a). Mia’s weekend physical activities were similar to Jamie’s with the exception that she also often played indoors with her friends and younger siblings. She was more active than Jamie and her MVPA was more consistent than his across weekends. With regards to family-based PA, the Evans family walked a lot on weekend days. However, these bouts of activity varied in duration, ranging from short visits to the local public park to whole-day family outings shopping and visiting the seaside. Subsequently, the Evans children’s MVPA levels, especially Jamie’s were variable across weekends (Figure 8.2a and b).

Box 8.2 Family case study for Williams family (Family 6)

The Williams family were of a higher SES than the study average (IMD 9.5 - quantile 2). They live in a cul-de-sac located in an affluent suburban neighbourhood with access to a self-contained garden. The family comprises of mother, father, and two children (Olivia, aged 7 and Harry, aged 9). Both parents are healthy weight, degree educated, and in part and full-time employment, respectively. Family-based PA appeared to be a key part of family life. The Williams family amassed their MVPA levels through a combination of organised sport and structured PA. All made regular use of their health club membership. The majority of Mrs William's PA took place at the health club and comprised a mixture of gym and group-based exercise. Mr Williams was also very active (Figure 8.3b). On almost all weekends, he used the gym at the health club, cycled with friends and coached his local football team. The Williams children recorded high MVPA levels across weekends (Figure 8.2a and b). Organised club sport formed the basis of Harry's and Olivia's weekend PA. On all but one weekend (weekend 3) Harry played football for his local team and Olivia played Tennis at the health club. The Williams children reported single occurrences of ice skating, swimming, golf, and trampolining, and participated in walking and cycling as a family but on a less regular basis. Despite the Williams children living in a cul-de-sac, they reported few experiences of neighbourhood outdoor play. Instead, they used the family garden regularly for active play with friends. Harry's and Olivia's PA levels were stable across weekends and so were their parents' (Figure 8.3a and b).

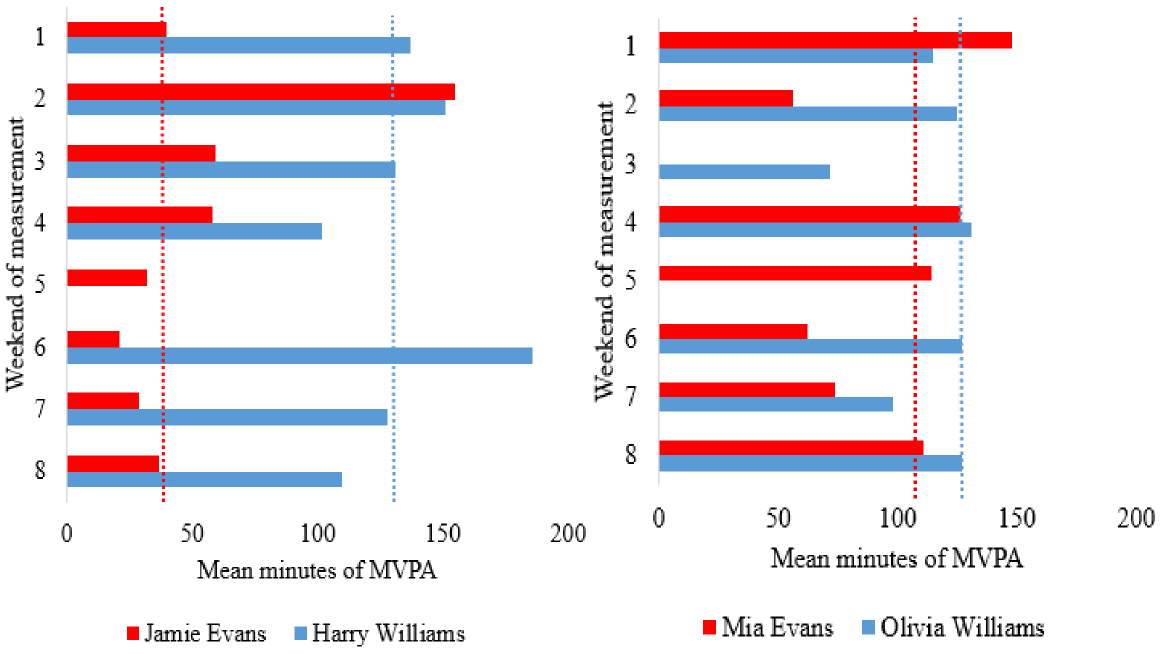


Figure 8.2a target children's and 8.2b siblings' mean MVPA comparisons for each weekend. Median MVPA across the 8 weekends for each family is represented by the dotted lines.

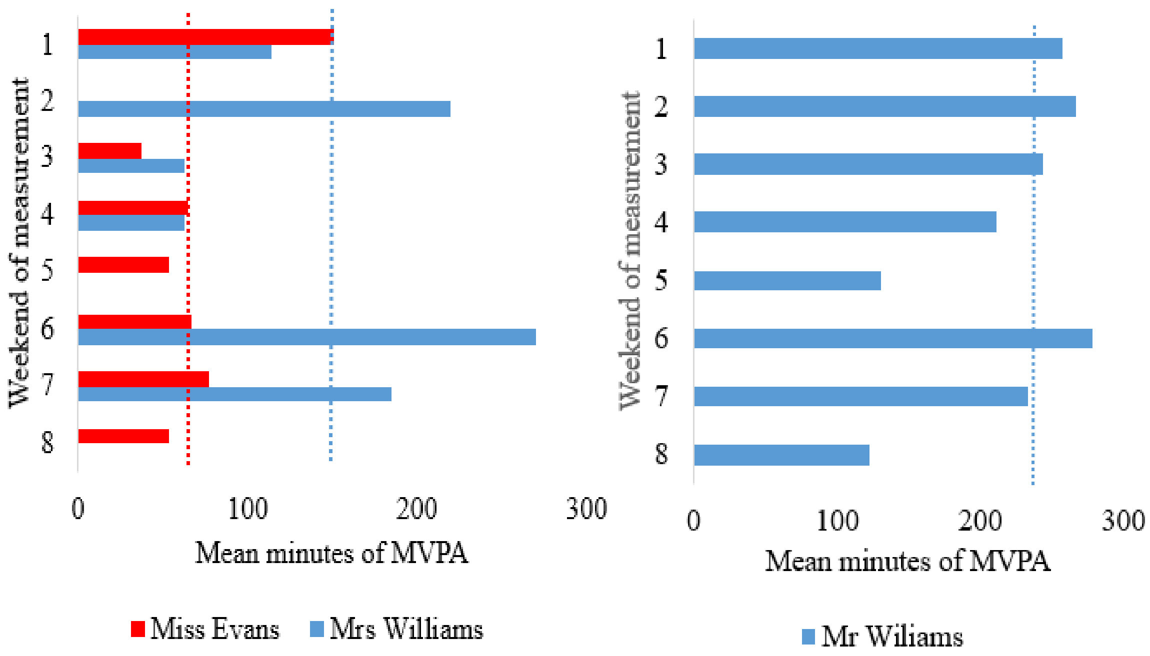


Figure 8.3a mothers' and 8.3b fathers' mean MVPA comparisons for each weekend. Median MVPA across the 8 weekends for each family is represented by the dotted lines.

## 8.4 Discussion

This study used a repeated measures design and multiple data sources to explore the variability and characteristics of weekend PA among families. The study observed substantial variability in children's weekend PA, and revealed that children's weekend PA is mostly unstructured in nature and undertaken with friends. The supplementary family case studies (Box 8.1 and 8.2) demonstrated that in the selected cases, MVPA levels and variability across weekends were contingent on mode of PA participation.

The study revealed that parents' MVPA was more stable across weekends than children's, and was most stable among fathers (ICC = 0.83) compared to mothers (ICC = 0.58). No previous study has examined PA variability between children and parents, but higher ICC values have been reported in men compared to women for objectively measured total PA over 7 days (Scheers et al. 2012). Similar repeated measures studies have been conducted with adults (Levin et al. 1999; Matthews et al. 2002). For example, Levin et al. (1999) assessed PA (MET min·day$^{-1}$) in 77 adults over 48-hours every 26 days for one year, and reported an ICC value of 0.42. The present study focused on weekend days and comprised a smaller sample and fewer repeated measures compared to the Levin et al. study. These factors are likely to have contributed to the higher ICC estimates observed in the present study.

The ICC values for weekend MVPA in target children (ICC = 0.55) and siblings (ICC = 0.38) in this study are lower than single observation studies in children (Addy et al. 2014, ICC = 0.81; Mitchell et al. 2015, ICC = 0.57 - 0.73; Rich et al. 2013, ICC = 0.76 - 0.97). However, they are consistent with repeated measures studies (e.g., Mattocks et al. 2007a; Wickel & Welk, 2010). Very few studies have examined variability in children's weekend PA using accelerometers and a repeated measures design. Mattocks et al. (2007) assessed 11- to 12- year-olds' PA over 7 days on 4 occasions and reported ICC values for total PA (counts per minute) of 0.54 for weekdays and 0.38 for weekend days. Together, these findings demonstrate that a single measurement period is unlikely to accurately represent a child's typical level of weekend PA, especially among younger children.

The investigation of specific sources of variance in weekend PA revealed that intra-individual variance (i.e., variation in PA from weekend-to-weekend within participants) accounted for a large proportion of total variance among children, especially when models were fitted without nesting the weekend effect within participants. This signified heterogeneous weekend PA patterns. Previous research has showed that children's PA levels are higher (Brooke et al. 2014) and more stable on weekdays compared to weekend days (Mattocks et al. 2007a), and most stable during the school day (Fairclough, Butcher, & Stratton, 2007). This is intuitive as the structured school day offers children various formal (e.g., physical education classes, after-school clubs) and informal PA opportunities (e.g., play time/recess) including travelling to and from school actively. When these structures, routines and opportunities are absent on weekend days, children's PA is thus partly dependent on peer and family-based PA opportunities, and strong parental encouragement (e.g., positive verbal reinforcement) and support (e.g., payment of club subscriptions, transport to and from provision) (Fairclough et al. 2015; McMinn et al. 2013). Neighbourhood environmental factors (e.g., access to garden/yard, leisure facilities and parks) are also likely influences on children's weekend PA (Oliver et al. 2016; Remmers et al. 2014a). The combination of these factors is likely to have contributed to the large intra-individual variability in children's weekend PA in this study.

The study findings build on previous family-based PA studies (Bentley et al. 2012; Brown et al. 2015; Davison et al. 2013) by providing contextual insight into weekend PA among family units. Children's weekend PA was mostly unstructured in nature and undertaken with friends, whereas a greater proportion of parents' weekend PA was undertaken alone in structured settings. With regards to family-based PA, popular weekend activities included walking, swimming and visiting public parks. The promotion of these activities may form appropriate intervention settings. Public parks play an important role in supporting PA, providing all families regardless of SES with the opportunity to walk, cycle, and play, with many having specific equipment/activities available for other health enhancing physical activities (Buchner & Gobster, 2007; Cohen et al. 2007; Han, Cohen & McKenzie, 2013). However, in order to promote regular park use among family units further investment in park programming may be required to provide a variety of features and activities within parks to support the needs of both children and parents (Cohen et al. 2010).

It was apparent from the two family case studies that in the selected cases, the mode of activity families engage in on weekends influences their weekend MVPA levels. For example, the Williams' (i.e., high SES) PA levels were high and structured in nature whereas the Evans' (i.e., low SES) were low and unstructured in nature. These findings are consistent with previous studies in children (Brockman et al. 2009; Nielsen et al. 2012; White & McTeer, 2012) and adults (Federico et al. 2013; Makinen et al. 2012) which reported SES as a strong predictor of PA and organised sport. Weekend leisure opportunities, especially organised ones, generally cost money. Low income families are less likely to have the available logistical and financial resources needed to partake in such leisure opportunities frequently (Brockman et al. 2009; Hardy et al. 2010; Holt et al. 2011). Therefore, accessible, low-cost weekend PA interventions, such as organised walks, park use or home based activities, may be an appropriate PA intervention for the least active and lowest income families.

The combined use of accelerometers and diaries across multiple weekends provided data that offered contextual insight into the variability of weekend PA among family units. For example, PA levels across weekends were more stable in the Williams family compared to the Evans family. The Evans family accrued all of their weekend PA by way of unstructured activities whereas the Williams family participated in activities that were club-based and structured in nature. This finding is intuitive as organised sport participation is linked with higher levels of PA in children (Marques, Ekelund & Sardinha, 2016; Telford et al. 2016), and tends to be undertaken regularly, and at predetermined scheduled times. Such structure and routine was evident in Olivia's and Harry's PA diary data, but was quite the opposite for Mia and Jamie. By contrast, their PA levels across weekends were more varied, especially Jamie's, and showed no apparent routine or structure. These findings are important as they reveal the potential influence of structured PA participation on habitual weekend PA amongst the selected family units. They suggest that broader intervention approaches may be needed to provide structured leisure opportunities for families at weekends (Kokolakakis, Pappous & Meadows, 2015).

It is important to understand the barriers to mode-specific weekend PA behaviours so that strategies can be developed to increase children's participation in specific modes of weekend

PA. The family case studies illustrate the potential environmental barriers to children's weekend PA and thus highlight the importance of understanding family context and PA characteristics when planning PA interventions. For example, the Williams children have access to a self-contained garden whereas the Evans children do not. This home environmental feature influenced the location of children's outdoor play. This is a key finding for this family because promoting specific modes of weekend PA (i.e., outdoor play and organised sport) without considering such barriers and constraints is unlikely to support positive sustained behaviour change. As the barriers to participating in organised sport (e.g., financial cost) and unstructured PA (e.g., walkability, access to garden/backyard) vary considerably (McMillan, McIsaac & Janssen, 2016; Wijtzes et al. 2014), future PA interventions may be more effective if tailored to support a specific mode of PA.

In addition to these empirical findings, the present study makes a methodological contribution by demonstrating the limitations of one off assessments of weekend PA and single modality PA measurement. The combination of accelerometer and PA diary data allowed exploration of the activities family units undertook on weekend days. By selecting two different family units and comparing their weekend PA behaviours, the study was able to demonstrate a way to gain understanding of the complexity of family context, and how, in these cases, family weekend PA varies in mode, location, and variability. Therefore, the findings demonstrate the advantages of supplementing accelerometer data with contextual data, and highlight the importance of distinguishing between structured and unstructured PA participation when examining out-of-school and family-based PA.

This is the first study to investigate the variability of weekend PA among children and parents simultaneously. A unique aspect of the study is its repeated measures design and objective assessment of raw PA. In addition, the study used wrist-worn accelerometry and observed high participant compliance to device wear which improves the reliability of raw PA estimates (Herrmann et al. 2014). Firstly, this provides additional confidence in the study findings, and secondly, offers support that wrist accelerometry is a feasible method of PA assessment in children and adults. Moreover, the study assessed weekend PA among families and in doing so revealed new insights into an understudied and complex area of research. The combination of multiple data sources is another strength of the study. Specifically, the combined use of raw accelerometer and diary data allowed exploration of PA mode and who activity was undertaken with among family units. There are though some limitations. Firstly, the sample size was small, and the participants were all white British and generally healthy weight, which reduced the generalisability of the study. Secondly, participants consented to wearing an accelerometer and completing PA diaries on eight occasions. Therefore, selection factors relating to time availability and study interest may have contributed to a fairly homogeneous sample with active families more inclined to take part. This may have resulted in higher than normal PA levels for the sample. While the findings of this study may not be fully generalisable to other populations and geographical locations, the methods used here are novel and may have wider applicability, and scalability in future health-related research studies involving families.

### 8.5 Conclusions

The results of this study provide unique information regarding the variability and characteristics of weekend PA among family units. The study demonstrates the potential for using PA diaries in conjunction with accelerometers to provide understanding of the mode and contexts of out-of-school and family-based PA. Future studies using accelerometers should therefore consider the use of PA diaries to provide much needed contextual information. This information can provide contextual understanding as to why some children are more active than others, and may help inform context-specific PA interventions. In addition to promoting family-based weekend PA, strategies to improve neighbourhood design and remove financial barriers to leisure provision are needed. These should be investigated further as components of interventions to promote weekend PA among children and families.

**Thesis study map**

| **Study** | **Objectives and key findings** |
|---|---|
| Study 1: Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. | **Objectives:**<br><br>(1) To investigate differences in health-related, home and neighbourhood environmental variables between Liverpool children living in areas of high-deprivation and medium-to-high deprivation.<br><br>(2) To assess associations between these perceived home and neighbourhood environments and health-related variables stratified by deprivation group.<br><br>**Key findings:**<br><br>• High deprivation children had higher BMI z-scores and waist circumference and lower CRF compared to medium-to-high deprivation children.<br>• High deprivation children lived in less walkable neighbourhoods and were less likely to have access to a garden than medium-to-high deprivation children.<br>• PA was inversely associated with bedroom media and positively associated with independent mobility.<br>• Independent mobility was inversely associated with crime safety and neighbourhood aesthetics. |
| Study 2. Comparison of children's free-living physical activity derived from wrist and hip raw accelerations during the segmented week. | **Objectives:**<br><br>(1) To assess children's physical activity levels derived from wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ raw acceleration data. |

| | |
|---|---|
| | (2) To examine the comparability of physical activity levels between the two devices throughout the segmented week.<br><br>**Key findings:**<br><br>• Children's raw PA levels were lowest on weekend days.<br>• Wrist-worn GENEActiv and hip-worn ActiGraph GT3X+ derived raw PA levels are not comparable in children.<br>• The largest differences in GAwrist and AGhip derived raw PA were observed at the lowest intensity and during school hours. |
| Study 3. Write, draw, show, and tell: a child-centred dual methodology to explore perceptions of out-of-school physical activity. | **Objectives:**<br><br>(1) To use a novel combination of qualitative techniques to explore children's current views, experiences and perceptions of out-of-school physical activity as well as offering formative opinion about future intervention design.<br><br>**Key findings:**<br><br>• Parents served as both enablers (i.e., encouragement) and barriers (i.e., restricting participation) to children's PA.<br>• Involvement of parents and the whole family is a strategy that could be significant to increase children's PA levels.<br>• WDST is an inclusive, interactive and child-centred methodology which facilitates the exploration of a wide range of topics and enhances data credibility. |

| | |
|---|---|
| Study 4. Parental perceptions on children’s out-of-school physical activity and family-based physical activity. | **Objectives:**<br><br>(1) To explore parents' PA knowledge and perceptions of children’s out-of-school PA to formatively contribute to a family-based intervention design.<br><br>**Key findings:**<br><br>• Few children played outdoors.<br>• A range of social and built environmental factors influence parents’ decision making to allow their children to play outdoors.<br>• Perceived PA social norms, resources and opportunities, and neighbourhood environmental barriers influence children’s PA levels and activity mode.<br>• Consulting with parents in a formative sense prior to familial PA intervention may aid subsequent intervention recruitment and engagement. |
| Study 5. Context matters! Sources of variability in weekend physical activity among families: A repeated measures study. | **Objectives:**<br>(1) To investigate the stability of weekend MVPA among target children, siblings, and parents using repeated measures raw accelerometer data.<br>(2) To offer contextual insight into the characteristics of weekend PA amongst one representative low active family and one high active family.<br><br>**Key findings:**<br>• Children’s weekend MVPA is extremely variable.<br>• Children’s weekend PA was mostly unstructured in nature and undertaken with friends.<br>• Parents’ weekend PA was mostly undertaken alone in structured settings. |

| | |
|---|---|
| | • MVPA levels and variability across weekends was contingent on mode of PA participation in the selected families. |

# Chapter 9

# Synthesis of findings

## 9.1 Review of thesis

PA is a modifiable behaviour that provides broad ranging short and long-term physical and psycho-social health benefits for children (Janssen & LeBlanc, 2010; Poitras et al. 2016). Various school-based PA intervention programmes have been implemented to increase children's PA but many of these have met with limited success (Metcalf, Henley & Wilkin, 2012). Children's PA is particularly low during the out-of-school period (Brooke et al. 2014; Fairclough et al. 2015). Although the out-of-school period represents an opportune time to promote PA, contextual understanding regarding children's PA out-of-school is presently limited. In an attempt to fill this research gap, the thesis has presented five studies, which each contribute novel elements to the existing body of literature on children's out-of-school PA.

The studies within this thesis were theoretically grounded and underpinned by Welk's (1999) YPAP model. The model embraces multiple theoretical perspectives and provides a bottom-up approach to understanding the multidimensional influences on children's out-of-school PA. Within the context of the behavioural epidemiology framework, the research presented in this thesis furthers scientific understanding of the methods used for measuring and understanding children's out-of-school PA (Phase II) and modifiable factors that influence children's out-of-school PA (Phase III). This section of the thesis will summarise the novel contribution each of the studies has made to the existing literature, and summarise the strengths and limitations of the thesis. The chapter will set the scene for the proposed research and practice related recommendations provided in the final chapter.

Traditionally, studies investigating child PA correlates have not examined the broader social and environmental determinants shaping children's PA choices (Buchan et al. 2012). Study 1 (Chapter 4) examined a broad range of individual, family, and environmental factors related to children's PA and health. Findings revealed that children living in high-deprivation areas had higher BMI z-scores and waist circumference, and lower CRF scores than children living in medium-to-high deprivation areas. The strengths of the study were in its assessment of a broad range of health indices, and in doing so, provided a thorough assessment of health markers building on previous research examining the relationship between deprivation and child health (El-Sayed, Scarborough & Galea, 2012; Nau et al. 2015; Schwartz et al. 2011; White, Rehkopf & Mortensen, 2016).

Study 1 (Chapter 4) was also unique in that it was the first UK study to examine the influence of neighbourhood characteristics on children's self-reported PA using the Neighbourhood Environment Walkability Scale for Youth (NEWS-Y). High-deprivation children had less access to self-contained gardens/yards and lived in less walkable neighbourhoods. These findings are broadly consistent with previous research (Donkin et al. 2014; Reading, 1997) particularly those evidenced in the Marmot Review, *Fair Society Healthy Lives* (Marmot, 2010) which highlighted that the more deprived the neighbourhood, the more likely it is to experience higher rates of crime, more risks to safety from traffic, and lack of green spaces for children to play in which in turn presents risks to health. Overall, the findings indicate that children living in highly deprived neighbourhoods represent an important target group for future PA and health interventions. Moreover, the findings provide further support for structural policy approaches that target environmental PA barriers to make it safe, convenient and economical for children to lead active lifestyles (Sallis, Owen & Fisher, 2008).

Interventions delivered during time periods susceptible to high levels of inactivity present the most opportune time to promote PA. Study 2 (Chapter 5) confirmed that the out-of-school period, specifically the weekend, is a key period prone to low MVPA. Moreover, study 2 (Chapter 5) found that PA levels derived from raw acceleration analysis were significantly higher for the wrist-worn GENEActiv than those for the hip-worn ActiGraph GT3X for all weekday and weekend day segments. This finding confirms that children's raw PA levels measured using wrist-worn GENEActiv and hip-worn ActiGraph GT3X are not comparable during free-living. The findings build on previous work (Fairclough et al. 2016; Hildebrand et al. 2014; Rowlands et al. 2014) by revealing differential agreement between the wrist-worn GENEActiv and hip-worn ActiGraph. Agreement differed according to PA intensity and time of day, with the greatest difference occurring in LPA during school hours. Together, these findings have implications for the field of PA measurement and surveillance. Firstly, there is a wealth of MVPA data on children estimated from uniaxial hip-worn ActiGraphs (Cooper et al. 2015; Corder et al. 2016; Goodman, Page & Cooper, 2014; Sherar et al. 2011). Secondly, there is a progressive move towards using the GENEActiv and other wrist-worn accelerometers in child PA research. Knowing that raw data are not comparable between wrist-worn GENEActiv and hip-worn ActiGraph reveals that correction factors are needed to improve the comparability of raw PA levels between studies using these devices and wear sites. Moreover, further research is warranted to compare estimates of MVPA derived from accelerations measured at the wrist and from ActiGraph counts measured at the hip.

Study 3 (Chapter 6), used a novel combination of qualitative techniques to explore children's current views, experiences and perceptions of out-of-school PA. This study was unique in that it built on existing qualitative methods. The WDST method represents an evolution of the write and draw and focus group method. A conceptual framework and practical checklist was presented to provide transparency of the methodological decisions made, and aid future replication by other researchers. Using children's views, recounted experiences and perceptions of out-of-school PA the findings presented in study 3 (Chapter 6) demonstrated how using a combination of inclusive, interactive and child-centred qualitative techniques may be advantageous when compared to traditional singular methods based approaches. The principal strength of the method is its potential to enhance credibility through triangulating multiple data sources and limiting researcher biases. Therefore, the WDST method serves to benefit future researchers aiming to elicit children's perceptions and experiences.

The findings from study 3 (Chapter 6) add to the evidence base on 'children's voice'. They also highlight and confirm the unique position parents are in with respect to promoting health enhancing behaviours. Paradoxically, parents were both enablers (i.e., encouragement) and barriers (i.e., restricting participation) to children's out-of-school PA participation. This finding confirms the need for parental/carer involvement in future out-of-school PA interventions. Findings from study 3 (Chapter 6) also reveal the need for interventions promoting active travel and outdoor play. However, the promotion and uptake of these unstructured forms of PA is likely mediated by independent mobility, and therefore dependent upon environmental and societal level changes to create safer neighbourhood spaces.

Study 4 (Chapter 7) used telephone interviews to explore parents' PA knowledge and perceptions of children's out-of-school PA. The findings presented in study 4 (Chapter 7) build on and supplement the findings reported in study 1 (Chapter 4) and study 3 (Chapter 6), and make known that outdoor play is an uncommon form of out-of-school PA. Specifically, the findings reveal detail on key factors that influence parents' decision making towards children's out-of-school PA and independent mobility. Consistent with prior research (O'Connor & Brown, 2013) parental safety concerns relating to 'stranger danger' and 'road traffic' were the most consistent barrier to children's independent mobility. Neighbourhood social norms were also a key contributing factor. The combination of these social and built environmental factors increased the appeal of adult supervised organised out-of-school PA. The supplementary family case studies presented in study 4 (Chapter 7) extend beyond traditional qualitative analysis approaches, and represent how parental knowledge, perceptions and constraints can influence children's PA levels and activity mode (i.e., active school travel, outdoor play and organised sport). Such constraints include factors such as, school proximity, neighbourhood perceptions and family context. These factors need to be considered when planning future interventions targeting specific modes of PA out-of-school.

Together these findings provide further evidence for PA interventions to promote unstructured forms of PA. They also emphasise the importance of taking note of family social norms, available resources and opportunities, and neighbourhood environmental perceived barriers prior to out-of-school PA intervention design. Promoting specific forms of PA (i.e., active travel, outdoor play, organised sport) without considering such factors is unlikely to support sustained positive behaviour change as the barriers to each vary considerably. Structural policy approaches seek to understand and influence the persistence and/or disappearance of shared social practices such as walking to school, playing outdoors or accessing structured organised PA provision (Blue et al. 2016). It would appear from this research that large-scale population level increases in out-of-school PA is highly dependent on the redesigning of neighbourhood environments and policy changes that make it safe, convenient and economical for children to lead active lifestyles (Sallis, Owen & Fisher, 2008).

Study 5 (Chapter 8) used a repeated measures design and multiple data sources to explore the variability and characteristics of weekend PA among family units. A unique aspect of study 5 (Chapter 8) is the concurrent assessment of children's and parents' MVPA over 16 weekend days. The weekend was identified in study 2 (Chapter 5) as a period of low MVPA and thus an important time period for future child PA interventions. Study 5 (Chapter 8) builds on study 2 (Chapter 5) by revealing substantial variability in children's weekend MVPA. The ICC value for children was consistent with previous research that used accelerometers and a repeated measures design (Mattocks et al. 2007a). Together, these findings demonstrate that a single measurement period is unlikely to accurately represent a child's typical level of weekend PA.

Although there is strong evidence that children are least active on weekend days (Brooke et al. 2014; Fairclough et al. 2015), little is known about the characteristics of children's weekend PA including PA mode and who they undertake activity with. The findings of study 5 (Chapter 8) build on previous out-of-school and family-based PA studies by providing contextual insight into weekend PA among family units. Children's weekend PA was mostly unstructured in nature and undertaken with friends, whereas a greater proportion of parents' weekend PA was undertaken alone in structured settings. With regards to family-based PA, popular weekend activities included walking, swimming and visiting public parks/green spaces. The promotion of these activities may form appropriate intervention contexts. The supplementary family case studies demonstrated that in the selected cases MVPA levels and variability across weekends was contingent on the mode of PA participation. This finding enhances understanding of the contextual factors that may influence children's weekend PA opportunities and behaviours.

Study 5 (Chapter 8) also makes a methodological contribution. Accelerometers and PA diaries were used in combination in study 5 (Chapter 8). The combination of methods provided an objective assessment of children's weekend MVPA and revealed contextual understanding of PA mode and who children undertook weekend activities with. In doing so, the data revealed differences in PA characteristics between case study children. This contextual information would have remained unknown had the study used accelerometers on their own. Therefore, future studies investigating children's weekend and family-based

PA should consider the use of accelerometers in conjunction with PA diaries to overcome the weaknesses in each method, and provide much needed contextual information on leisure time behaviours.

### 9.2 Methodological strengths and limitations

The strengths and limitations of each study were discussed briefly in previous chapters, but are explored in more detail here.

#### 9.2.1 Physical activity measurement in children

PA was assessed using the PAQ-C in study 1 (Chapter 4). The PAQ-C is a well-established and validated tool which continues to be recommended in youth PA research (Biddle et al. 2011b; Saint-Maurice et al. 2014a; Thomas & Upton, 2014). However, the inability of the PAQ-C to calculate time spent in MVPA limits discussion of results in relation to public health PA guidelines. Furthermore, the PAQ-C may be subject to recall issues and social desirability (Dollman et al. 2009). PA was assessed using accelerometers in studies 2 (Chapter 5) and 5 (Chapter 8). Accelerometers provide valid and reliable assessments of PA at varying intensities in children (Butte, Ekelund & Westerterp, 2012; de Vries et al. 2009). A key strength of this thesis is the use of contemporary accelerometer data processing methods. Study 2 (Chapter 5) and study 5 (Chapter 8) used tri-axial wrist-worn accelerometers and raw data processing methods. Wrist-worn accelerometers are known to improve compliance to device wear thereby reducing data loss and improving PA estimates (Fairclough et al. 2016).

Participant compliance to device wear in study 5 (Chapter 8) was high (target children, 13.4 hours ± 1.8 hours; siblings, 13.8 hours ± 1.9 hours; mothers, 14.1 hours ± 1.6 hours; fathers, 13.5 hours ± 1.4 hours). The consistent high mean participant wear-time provides additional confidence in the findings reported in study 5 (Chapter 8), and adds further support for the use of wrist-worn accelerometry as a feasible measure of free-living PA. Moreover, the mean PA levels presented in study 5 (Chapter 8) are based upon 8 repeated measures. Compared to single observation measures these findings provide a more accurate representation of habitual PA. For the purpose of study 5 (Chapter 8) the step count display on the ActiGraph

GT9X was deactivated as to not influence the participant's PA levels (i.e., Hawthorne effect; Wickstrom & Bendix, 2000). The step counter was not appropriate for the research aims of this thesis but may have advantages for future PA intervention studies aimed at increasing children's daily ambulatory steps. Future studies should consider using the ActiGraph GT9X. Firstly, the wrist-worn device has time display capabilities which may further enhance device wear. Secondly, it is able to capture and store raw acceleration data which can add to the existing body of research on children's raw PA levels.

Compared to traditional count based approaches, raw acceleration signal processing offers greater control over data reduction, allowing comparisons to be made more easily between studies using different raw accelerometer devices (Fairclough et al. 2016; Hildebrand et al. 2014). In both study 2 (Chapter 5) and 5 (Chapter 8), accelerometers were programmed to collect data at high sampling frequencies (100 Hz and 30 Hz) and signals were summed over a short epoch (≤ 5 seconds). This ensured that children's vigorous and intermittent activity patterns were captured and in doing so limited the chance of MVPA misclassification (Baquet et al. 2007; Edwardson & Gorely, 2010a). The MVPA raw intensity cut-point thresholds used in study 2 (Chapter 5) and study 5 (Chapter 8) were device and placement specific, and consistent with other studies (Fairclough et al. 2016; Hildebrand et al. 2014). This enabled the findings in both studies to be compared against prior research. Likewise, the non-wear and wear time criteria used in study 2 (Chapter 5) and study 5 (Chapter 8) were consistent with similar studies (Fairclough et al. 2016; van Hees et al. 2013). As the focus of these studies was on MVPA rather than sedentary time, non-wear decision rules are unlikely to have had a significant effect on the study findings.

Despite the combined efforts of this thesis and recent published work (Fairclough et al. 2016; Hildebrand et al. 2014; Rowlands et al. 2014; 2015; 2016a; 2016b) robust implementation of raw accelerometry in PA research is challenged by the need for methodological consistency. The combination of increased freedom given to the user/researcher by access to raw data and the lack of consensus and standardisation on raw data processing procedures is likely to result in broad dissimilarities in signal processing techniques. This will complicate and limit the comparison of outcome measures across studies using different signal processing methods. Therefore, scientific journals should encourage compulsory sharing of signal processing techniques in manuscripts to facilitate greater transparency of the methodological decisions employed by researchers during analysis enabling future studies to replicate methods.

Presently, there is no ‘gold standard’ instrument capable of assessing all dimensions of children’s PA simultaneously. Accelerometers are limited in that many devices are unable to capture water-based activities (i.e., swimming) and non-ambulatory activities such as cycling (Tarp, Andersen & Østergaard, 2015). These activities tend to be more prevalent during the out-of-school period when children have increased discretionary time and partake in family-based activities (Goodman, Mackett & Paskins, 2011). PA was assessed in the same segment (i.e., weekend) during all measurement waves in study 5 (Chapter 8). Therefore, the inability of the accelerometer to capture these aforementioned activities is unlikely to have influenced the findings presented in study 5 (Chapter 8). Moreover, self-report diaries were used in conjunction with accelerometry to confirm what activities children participated in on weekend days. Although PA was assessed across different segments in study 2 (Chapter 5), the findings are consistent with previous studies that also reported low PA levels on weekend days compared to weekdays (Brooke et al. 2014; Fairclough et al. 2015). Future studies may benefit from using a combination of innovative methods to capture information on PA setting and context to help inform the children’s PA patterns.

Future research exploring children’s out-of-school PA may benefit from using Global positioning system (GPS) monitoring technology (e.g., GPS loggers or GPS-enabled mobile phones). GPS provides a direct assessment of children’s spatial activity and mobility patterns over extended time periods. When used in combination, GPS and accelerometry data provides understanding of PA location (McCrorie, Fenton & Ellaway, 2014). Combining these two data sources with geographic information system (GIS) data can provide valuable information on environmental factors that influence children’s PA behaviour out-of-school. GIS may also serve as an integrative tool capable of transcending the traditional quantitative-qualitative divide, allowing PA researchers to investigate more robustly the influences and implications of the built environment on children’s PA and health (Thornton, Pearce & Kavanagh, 2011). Therefore, further research is warranted to build on the existing GPS

(Jones et al. 2009; Loebach & Gilliland, 2014; Maddison et al. 2010; Maddison, & Mhurchu, 2009; Quigg et al. 2010; Wheeler et al. 2010) and GIS evidence base (Brondeel, Pannier & Chaix, 2015; Burgoine et al. 2015; Harrison et al. 2014; Kyttä et al. 2012; Loebach & Gilliland, 2016; Mitchell, Clark & Gilliland, 2016) by investigating built environmental influences on children's mode-specific PA, and children's spatial PA patterns on weekend days. The complex data sets resulting from the integration of these multiple data sources will likely require specialist knowledge and software to combine and interpret. Therefore, effective collaboration between PA researchers and data analysts may be key to overcoming this challenge.

### 9.2.3 Selection bias and generalisability

Participants for all studies in this thesis were recruited from a range of schools and SES areas within Liverpool, England. The findings may not be representative of the wider UK population as data were collected from one highly deprived area of the UK. However, throughout all quantitative chapters in the thesis baseline tests were conducted to determine whether characteristics of participants included in analyses differed from those excluded. There were no significant differences between participants included and excluded from the analysis within each study therefore, selection bias is unlikely to have influenced the internal validity of the findings presented throughout the thesis. Participant response rates for some studies in the thesis were low. This may have biased the results in a positive direction. For example, active children may have been more likely to take part in the study. Additional research is required to confirm the findings presented here and to investigate whether associations differ in other areas of the UK. Furthermore, the parents in Chapter 7 were mostly married and degree educated and their children were of white ethnic origin and normal weight status. The relatively high socioeconomic background of participants and characteristics of the children may limit wider application.

### 9.2.4 Observer bias

Observer bias occurs when there are systematic differences in the way data is collected, measured or interpreted by the researcher or researchers for the participants being studied (Thomas, Nelson & Silverman, 2011). Various steps were taken to minimise observer bias throughout this thesis. Firstly, standardised data collection methods were used for each study

(Smith & Noble, 2014). For example, prior to data collection in study 1 (Chapter 4) training was delivered for research assistants so that each research assistant understood the research protocol and correct standardised procedures. This minimised observer bias (Pannucci & Wilkins, 2010). Moreover, throughout data collection, each anthropometric and fitness measure was taken by the lead investigator to increase reliability. Furthermore, prior to completing questionnaires children were provided with the same set of instructions (i.e., not a test, no right or wrong answers, only interested in what you think, ask if you need help), and research assistants were on hand during the completion of questionnaires to offer children support where necessary.

### 9.2.5 Confounding

Throughout this thesis, potential confounding variables were included in multivariate models. The possibility of the associations presented here being influenced by confounding factors is therefore low. Efforts were also made throughout the thesis to minimise residual confounding. This was achieved by assessing a broad range of potential confounders and measuring them with as much accuracy as possible. For example, anthropometric measures were taken by the principle researcher for all studies in the thesis which significantly increases the reliability of the data and reduces measurement error (i.e., between researcher bias) (Thomas, Nelson & Silverman, 2011).

### 9.2.6 Chance

Although chance can never truly be ruled out, statistically significant associations presented in this thesis were lower than $p<0.05$, were in a consistent direction and similar magnitude, and were also in agreement with previous findings. Such factors increase confidence in results and suggest that the findings presented throughout the thesis are not due to chance.

### 9.2.7 True relationship

Correlational research is the weakest research design for causal evidence but these types of studies are needed in the preliminary stage of knowledge and intervention development to generate hypotheses and provide measures of association (Grimes & Schulz, 2002b). Factors associated with PA in correlational research can then be used as outcome and exposure measures in experimental studies to determine whether a cause-effect relationship exists and whether increases in exposure led to outcome increases, in this case PA. Because the exposure and outcome variables were measured at the same time point in the cross-sectional research chapters, causation cannot be confirmed (Thomas, Nelson & Silverman, 2011). Experimental research is therefore needed to test associations reported here and to confirm whether the recommendations for future intervention design presented here are effective.

### 9.3 Reflection

From a personal perspective, the research process has been an enormous learning and developmental experience. My knowledge base and research expertise have expanded tremendously through use of a range of quantitative and qualitative research methodologies. These include anthropometry, questionnaires, diaries, accelerometry, raw signal processing, write and draw, focus groups, and telephone interviews. In addition, my personal assumptions regarding individual health choices have been deconstructed in response to exploring health concepts from an ecological and societal perspective. In doing so, I have developed a broader more critical outlook of health behaviour and the world in general. For this I am extremely thankful.

### 9.4 Summary and conclusions

This thesis has enhanced understanding of children's out-of-school PA. Importantly, the research has identified common facilitators and barriers associated with children's out-of-school PA. The findings have evidenced that children's out-of-school PA is lowest at weekends, and influenced by a complex interaction of individual, social and environmental factors.

Peer PA co-participation was reported as a strong influence on children's out-of-school PA in Chapter 6 and children undertook most of their weekend PA with friends in Chapter 8. This finding suggests that there may be benefit in providing opportunities for children to participate in PA with their peers. Structured out-of-school PA programmes could be formed for children that partner them with other peers to participate in physical activities, creating a system of social support. These activities may form part of the extended school day using revenue from the newly introduced soft drinks industry levy (Barber & Sutherland, 2017). Moreover, parents could help foster support within the peer network by providing their children autonomy to play outdoors in the neighbourhood with their peers.

Within this thesis, it was evident that parents play a key role in their child's out-of-school PA. Findings in Chapters 4, 6, 7 and 8 demonstrated that parents influence their child's out-of-school PA in a variety of ways, which suggests that out-of-school PA intervention programmes should incorporate parents. Parents provided a broad range of tangible support through financing subscription costs and sports equipment, transporting children to activities and clubs, watching children participate in activities, and engaging in activities with children. They also provided intangible social support via the motivational encouragement and praise they gave to their children. Targeting such facets of the social environment offers a potentially useful avenue for interventions designed to increase child out-of-school PA.

Key barriers to children's out-of-school PA include the neighbourhood environment and restricted independent mobility. The thesis has also revealed that the barriers to children's out-of-school PA are activity mode dependent. While modifications to the built environment may provide neighbourhoods that are more conducive to outdoor play and active travel, there are additional social-environmental factors that must be considered and addressed for these programmes to work effectively. The promotion of out-of-school PA requires a multi-sector approach to intervention that provides structured low-cost PA opportunities for children and environments that support their active living. Strong collaborations between researchers, public health, schools, local government, transport agencies and urban planners are critical to translate research in to practice.

Chapter 8 demonstrated that families engage in different levels and modes of weekend PA. Providing families with generic information about increasing family-based PA is unlikely to modify the coordinated and synchronised set of family practices (e.g. working, finances) into which PA fits (Blue et al. 2016). Future family-based PA interventions may be more effective if informed by family characteristics, and tailored to support participation in a specific mode of PA. Aligning intervention content to the needs, characteristics and constraints of the family will ensure that programmes are relevant and in doing so may positively influence intervention recruitment, engagement and effectiveness.

Current UK health policies exert responsibility for health and active living on the individual and in children's case parents (Department of Health, 2011; HM Government, 2015). However, only a structural analysis can explain why PA levels are low among many UK children (Griffiths et al. 2013; Lieberman, Golden & Earp, 2013; The Health and Social Care Information Centre, 2013). The research presented in this thesis imparts a new narrative and has shed light on the broader social and environmental influences on children's out-of-school PA. In doing so it provides recommendations (see Chapter 10) that extend beyond individualistic conceptions of children's PA and health.

# Chapter 10

# Recommendations for future work

## Recommendations for future work

Based on the findings presented in this thesis there are several recommendations to further the line of research on out-of-school PA and PA measurement in children. These recommendations have been organised below into priorities for research and practice.

### 10.1 Recommendations for practice

- Future child PA interventions should be delivered during the out-of-school period.
- PA promotional strategies should include parents and emphasise broader PA health benefits aside from weight reduction and maintenance.
- Researchers, health practitioners, transport agencies and urban planners should work in collaboration to design neighbourhoods that are supportive of active living (i.e., outdoor play and active travel).
- Media avenues should be encouraged to provide positive images of children participating in a wide range of activities including outdoor play and active travel.
- Health practitioners and local newspaper and radio stations should work in partnership to broadcast a range of health-enhancing opportunities for children including safe play areas, walking and cycling routes.
- Schools, Local Education Authorities and urban planners should work in partnership to promote and facilitate active travel to school programmes. Where possible, parents should be discouraged from driving their children to school.
- School playgrounds and facilities should be accessible for community use to promote PA out-of-school hours.
- Schools should support the promotion of child PA and family involvement in PA research by way of health related homework tasks and family fun days.
- The Department for Health should think more broadly about active living and recognise important contributing factors to health such as social inequalities that serve as fundamental drivers to PA behaviour.
- The Department for Health PA guidelines should place greater emphasis on unstructured forms of PA (i.e., active travel and outdoor play) rather than organised sport that involves financial cost.

- The Department of Health and the Department for Education should work in conjunction to expand the programme of after-school activities delivered at schools to provide access to children from low SES backgrounds.
- Future PA interventions and health policies should be tailored to those in greatest need.

## 10.2 Recommendations for research

- Where feasible, future PA studies should use wrist-worn accelerometers to improve compliance to device wear.
- Future PA studies using accelerometry should use a 24-hour protocol to increase device wear.
- Decision rules for the processing of raw acceleration data need to be standardised to facilitate comparison of findings between studies.
- Additional research is needed to explore the relationship between independent mobility, neighbourhood social norms and SES.
- Future research exploring children's PA perceptions should employ techniques such as the write, draw, show and tell methodology to elicit children's voices, facilitate the exploration of a wide range of research topics and enhance data credibility through limiting researcher biases and triangulating data sources.
- Further research is needed to establish how to increase children's PA levels on weekend days.
- Future out-of-school interventions should be informed by an understanding of family experiences and ecology, and tailored to account for individual family needs and constraints.
- Further research is needed with parents/carers and families to identify effective strategies to recruit, engage and support them in intervention programmes.
- Further process evaluation of out-of-school and family-based interventions is warranted to inform future research and practice.
- Future estimates of habitual PA should be based on repeat measurements of PA.
- Future studies using accelerometers should consider using PA diaries to supplement the accelerometry data and provide much needed contextual information.

### 10.3 Recommendations for family participant recruitment

Recruitment and retention barriers in behavioural health studies, particularly those involving families are well known (Schoeppe et al. 2013b). Based on work undertaken as part of this thesis I have outlined below several factors that may contribute towards family-based recruitment and retention in the future.

- Undertake formative work pre-intervention to understand the target audiences' perceptions and constraints.
- Identify effective ways to communicate with parents during the research project.
- Build trustful relationships with study participants throughout the project via continual communication and dialogue using appropriate mechanisms such as SMS messaging, social media or email.
- Schools are gatekeepers to participant recruitment. Rather than relying on information and flyers to recruit families for research studies:
- Generate enthusiasm in potential child participants prior to the distribution of recruitment information by explaining to them at school the purpose of the research and the processes involved.
- Emphasise the benefits of study participation to parents/carers that extend beyond physical health benefits (i.e., weight reduction).
- Offer monetary incentives to families for participating in the research.
- Provide schools and families with a tangible outcome for their participation in the research such as individualised feedback in the form of an executive summary report or infographic.
- Minimise the burden to study participants by using wrist-worn monitors that serves dual purposes (time and PA assessment).

# Chapter 11

# References

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# Chapter 12

# Appendices

## Appendix A

**Noonan, R. J.,** Boddy, L. M., Knowles, Z. R., & Fairclough, S. J. (2016). Cross-sectional associations between high-deprivation home and neighbourhood environments, and health-related variables among Liverpool children. *BMJ Open*, 6:e008693. doi: 10.1136/bmjopen-2015-008693.

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