Exploring and developing methods of assessing sedentary behaviour in children

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Abstract

Evidence suggests that sedentary behaviour (SB) is associated with adverse health outcomes. Children's SB is a complex set of behaviours that includes different types of activities taking place in a variety of settings. Therefore, assessing children's SB is challenging and currently no single method exists that captures the behaviour as a whole. This thesis aims to explore and develop new and existing methods of assessing children's SB, by employing a range of quantitative and qualitative methods. Accelerometry has become a widely used method of estimating sedentary time (ST). Study 1 identified raw acceleration thresholds to classify children's sedentary and stationary behaviours, using two accelerometer brands across three placements. Thresholds however, do not account for the postural element of SB, as per its definition. Study 2 validated the Sedentary Sphere method in children, allowing for the most likely posture classification from wrist-worn accelerometers. Study 3 added contextual information to accelerometer data by using a digitalised data capturing tool, the Digitising Children's Data Collection (DCDC) for Health application (app). Children used the app to report their SBs daily through photos, drawings, voice recordings as well as answering a multiple-choice questionnaire. Results from the DCDC app identified specific SBs to be targeted in future interventions. Data showed distinct differences between boys and girls' screen-based behaviours, suggesting gender-specific interventions are needed to reduce screen time. Using the DCDC app in combination with accelerometry often explained patterns of SB and physical activity observed in accelerometer data. Study 4 added information about parents' perceptions of the factors that influence their children's SBs. This study identified parents/carers as a target for future interventions in view of perceptions reported about PA and SB and their need for support to help reduce the time children spend using screen-based devices.

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Publications and communications

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Abbreviations

Abbreviation	Definition
ASAQ	Adolescent Sedentary Activity Questionnaire
AG	ActiGraph
ANOVA	Analysis of variance
APHV	Age at peak height velocity
app	Application
AUC	Area under the curve
CAR	Computerised activity recall
CI	Confidence intervals
DCDC	Digitising Children's Data Collection
DO	Direct observation
Dom	Dominant
EMA	Ecological momentary assessment
ENMO	Euclidean norm minus one
g	Gravity
GA	GENEActiv
hrs	Hours
ICAD	International children's accelerometer database
ICC	Intra-class correlation coefficients
IG	Intensity gradient
IMD	Indices of multiple deprivation
IPAQ	International Physical Activity Questionnaire
LPA	Light intensity physical activity

MAPE	Mean absolute percentage error
MARCA	Multimedia Activity Recall for Children and Adolescents
MET	Metabolic equivalent of task
min	Minutes
MPE	Mean percentage error
MVPA	Moderate-to-vigorous intensity physical activity
n	Sample size
Ndom	Non-dominant
PA	Physical activity
Pre-PAQ	Preschool-aged Children's Physical Activity Questionnaire
PDPAR	Previous day physical activity recall
ROC	Receiver operating characteristic
SB	Sedentary behaviour
SBSS	Sedentary behaviour and Sleep Scale
SBR	Sedentary behaviour record
SBRN	Sedentary behaviour research network
SD	Standard deviation
SES	Socioeconomic status
SOS	Systems of sedentary behaviours
SS	Sedentary Sphere
SSA	Supporting server application
ST	Sedentary time
SVM	Signal vector magnitude
TA	Tablet application
TNR	True negative rate

TPR	True positive rate
TV	Television
UK	United Kingdom
YAP	Youth Activtiy Profile

CHAPTER 1

INTRODUCTION

1.1 The research problem

The benefits of physical activity (PA) to children's health and well-being are well-known (Janssen and LeBlanc, 2010; Poitras et al., 2016). However, the PA levels of children worldwide are low (Hallal et al., 2012; Aubert et al., 2018) and this inactivity has been called a global pandemic because of its association with ill health (Kohl et al., 2012). In 2006, Spanier and colleagues published an article called "Tackling the obesity pandemic: a call for sedentary behaviour research", in which the authors advised researchers to stop focussing on what children are *not* doing (i.e. not reaching recommended PA guidelines) and instead shift their focus to what children *are* doing (i.e. sedentary behaviours) (Spanier, Marshall and Faulkner, 2006).

A search using the terms "sedentary" and "children" yielded 4,170 citations between 2006 and 2016 on Web of Science, 15,640 on Pubmed and 32,000 "hits" on Google Scholar. Despite the vast amount of research focussing on the SBs of children over the past decade, many questions remain unanswered. Clear links between children's SBs and health indicators have not been established, children's levels of SB are largely unknown, evidence of the determinants of children's SBs are sparse and until 2017, there was no formalised consensus definition of SB. Systematic reviews regarding children's SBs bemoan the low quality of studies and lack of evidence in the literature (Tremblay et al., 2011; Carson et al., 2016a; Stiglic and Viner, 2019). This is mainly due to the fact that SB is a complex set of behaviours encompassing various types of activities, which can take place in a range of settings (Biddle, 2007; Pate, O'Neill and Lobelo, 2008).

The complex nature of SB makes it challenging to capture accurately. Traditionally, self-report questionnaires (or in the case of young children, proxy-report by a parent/carer) have been used to measure SB (Lubans et al., 2011; Atkin et al., 2012). However, self- and proxy-report tools are known to be susceptible to recall errors, misrepresentations and social desirability (Loprinzi and Cardinal, 2011; Atkin et al., 2012; Hardy et al., 2013). More recently, accelerometry has become a widely accepted device-based method of measuring SB, by classifying little or a lack of movement as time spent in sedentary activities (Atkin et al., 2012; Cain et al., 2013). However, accelerometers are unable to provide important contextual information, like what types of activities children engage in, or the settings in which these activities take place. This presents a gap in the literature, as there is no standardised method able to assess children's SB comprehensively.

The aim of this PhD research was to explore and develop new and existing methods of assessing SB in children. Specifically, the objectives of the PhD were to:

- Conduct a calibration study to identify raw acceleration sedentary thresholds for wrist and hip-worn monitors from a wide range of SBs in children (Chapter 4),
- Validate the Sedentary Sphere method of posture classification via wrist-worn accelerometers in children (Chapter 5),
- Explore the efficacy of using a digitalised data capturing tool in combination with accelerometry, in order to capture children's SB more comprehensively (Chapter 6), and
- Explore parental perceptions of the factors influencing children's SBs (Chapter 7).

1.2 Organisation of the thesis

Chapter 1 introduces the research problem briefly and defines the primary aims and objectives of this PhD. It also introduces the researcher and her positionality within the research process. Chapter 2 highlights the research problem and rationale for the subsequent chapters, by critically reviewing the current literature. Methods used consistently across the studies are described in Chapter 3, whilst more detailed or study specific methods are included in the relevant study chapters. Chapters 4 to 7 describe in detail the different studies conducted during the PhD, forming the body of this research. Finally, Chapter 8 synthesises the findings of all preceding chapters, highlights strengths and limitations of the research and provides recommendations for future work.

The behavioural epidemiology framework (Sallis, Owen and Fotheringham, 2000; Owen et al., 2010) informed this PhD. The framework (Figure 1.1) consists of six phases of researching behaviour and health. Despite extensive research that has been conducted focussing on phase 1 (establishing links between children's sedentary behaviour and health) (e.g. Martinez-Gomez et al., 2010; Tremblay et al., 2011; LeBlanc et al., 2012), there is a need for more robust studies, using valid and reliable methods of measuring the behaviour before the links between SB and health can be firmly established. Studies 1, 2 and 3 of this thesis (Chapters 4-6) centre on phase 2 of the behavioural epidemiology framework, i.e. developing methods of measuring SB. Study 3 (Chapter 6) also identified contextual correlates, i.e. behaviour settings (Owen et al., 2000; Owen et al., 2010) in home, transportation and recreation contexts (phase 3), while Study 4 adds to our understanding of the factors influencing children's SBs (phase 4).

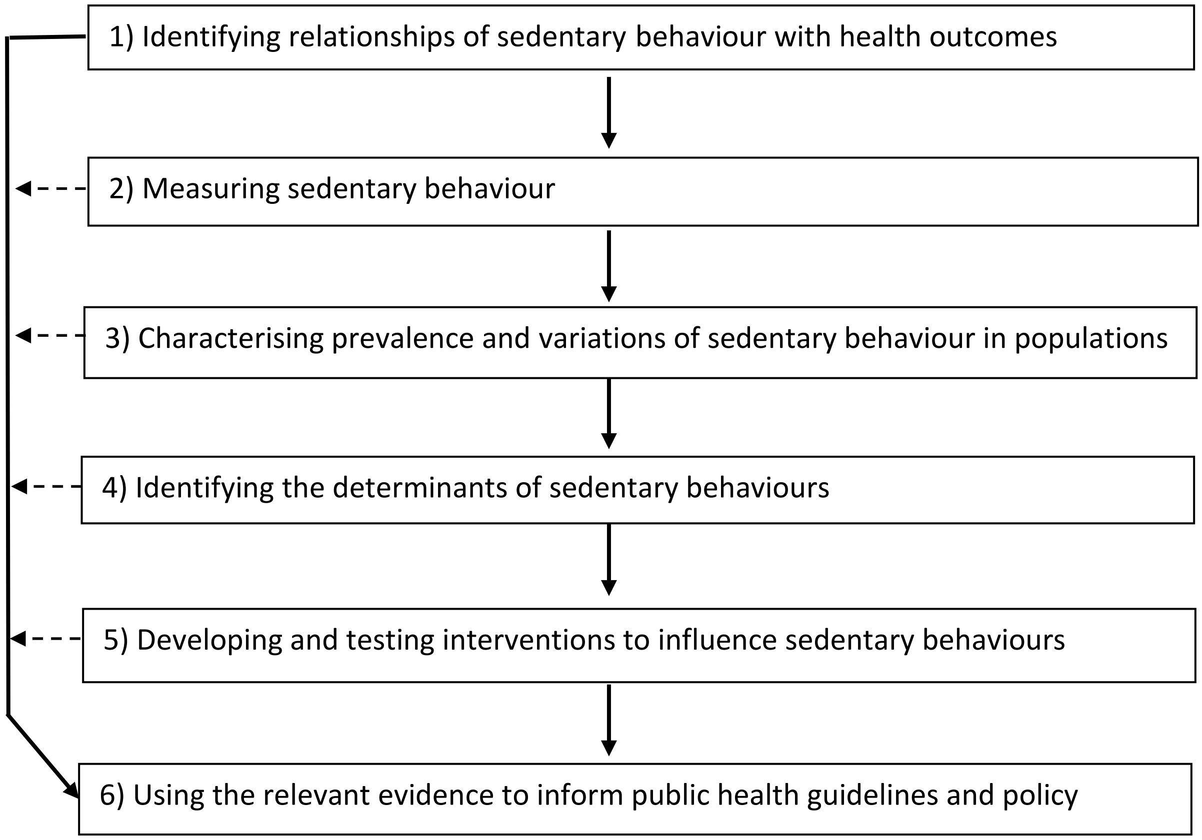


Figure 1.1: Behavioural epidemiology framework (Owen et al., 2010)

All four studies will inform future research aiming to develop interventions to change SB (phase 5). While each phase of the behavioural epidemiology framework naturally builds upon the previous phase, there are also non-linear elements (Sallis, Owen and Fotheringham, 2000). For example, the methods of measuring SB in children developed during Studies 1 to 3 of this PhD, can also be used to more clearly identify the relationship between SB and health (phase 1) in children, and ultimately, all the phases should inform public health policies (phase 6).

1.3. Introducing the researcher

Growing up on a farm in South Africa, I was a very active child who excelled in sport and always enjoyed being physically active. It was while doing my Master's thesis that I first became interested in the childhood obesity epidemic, and the effects that decreased levels of PA had on children. My own children's PA and SB levels were never something that concerned me, until we moved to the United Kingdom (UK). For the first six months (and for the first time in our children's lives), we stayed in a house without a garden, but luckily right next to an open field and nearby park. This was also the first time that we were confronted with limited daylight during the winter months, and I understood for the first time why many children in the UK do not meet the one hour of moderate-to-vigorous intensity PA (MVPA) per day, as recommended by the government. After two years in Liverpool, we moved south to Tunbridge Wells, in Kent. This means that I had the privilege of experiencing first-hand the differences between schools in Liverpool (schools recruited for my studies were all from high deprivation areas) and our children's new school in Tunbridge Wells (a low deprivation area). This experience has opened my eyes to the challenges faced by those living in deprived areas of the UK. For the majority of my PhD studies, all four of our children were in primary school, with our daughter (the eldest) being the same age as the participants in Studies 1 to 3. This helped me to make informed decisions when writing child assent forms and information sheets for Studies 1 to 3. I kept my own children's behaviours in mind when designing my studies, for example when choosing typical SBs to include in the calibration protocol of Study 1. Throughout my studies, I continuously observed my own children and specifically noticed how their behaviour changed with age and influence from their peers. I was conscious that my children often influenced my ideas, but conversations with members of my supervisory team challenged my notions of unconscious bias, for example when choosing typical behaviours for

Study 1 or analysing qualitative data during Study 4. Our daughter was one of the participants in Study 3. My position as researcher and mother of a child participant mainly becomes evident in Study 4, where I expressed my own personal views and opinions in reflexive stop-offs throughout the chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will summarise the recent advances in SB research in children. It will briefly highlight its evolving definition, current public health guidelines, its relationship with health, current levels of SB reported in children, as well as the known correlates and determinants of children's SBs. The different methods of measuring the behaviour will also be discussed in detail.

2.2 Definitions

2.3.1 A brief history of the definition of sedentary behaviour

The definition of SB has evolved over the past two decades. Until recently, a variety of definitions could be found in the literature. In a review of SB interventions for example, DeMattia, Lemont and Meurer (2007) simply defined SB as recreational screen time, ultimately reducing the behaviour to a single activity. Some studies defined the behaviour solely based on its energy requirements. For example, Owen et al. (2000) and Pate, O'Neill and Lobelo (2008) defined SB as all activities having a metabolic equivalent of task (MET) value between 1.0 and 1.5 METs. Derived from the Latin *sedere*, meaning "to sit", the postural element of SB cannot be ignored, hence a few years later Owen et al. (2010) and Pate et al. (2011) updated their definitions to include both low energy expenditure and a seated posture. Marshall and Ramirez (2011, p.519) went one step further by including the fact that SB encompasses a group of behaviours, defining it as "a distinct class of behaviours that involve sitting and low levels of energy expenditure, typically less than 1.5 metabolic equivalents".

In 2012, prompted by an increasing amount of studies investigating SB and its impact on health, 52 members of the Sedentary Behaviour Research Network (SBRN, an international network connecting SB researchers and health professionals) penned a letter calling for a standardised use of the terms “sedentary” and “sedentary behaviour”, specifically distinguishing it from “physical inactivity” (Sedentary Behaviour Research Network, 2012). Later, researchers called for the publication of consensus definitions of SB and related terms (Altenburg and Chinapaw, 2015; Boyington et al., 2015; Gibbs et al., 2015), in order to better facilitate comparisons between studies. In 2016, the SBRN embarked on a terminology consensus project to address this need with 87 members from 20 countries participating in the project. The results were published in 2017 (Tremblay et al., 2017) and nine terms related to SB were identified. Each term was given a general definition and several caveats were also included.

For the purpose of this thesis, SB is defined as “any waking behaviour characterized by an energy expenditure ≤ 1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture” (Tremblay et al., 2017, p.9). “Reclining” refers to a body position between sitting and lying, e.g. lounging on a couch. In children, examples of SBs include a number of screen-based behaviours like television (TV) viewing, playing with a mobile phone or tablet, computer time etc., as long as they are in a seated, reclining or lying position and not expending energy above 1.5 METs. Non-screen-based SBs range from reading, writing, drawing, doing homework, to playing with toys, sitting in a car etc. One caveat of SB is sedentary time (ST), referring to “the time spent for any duration (e.g., minutes per day) or in any context (e.g., at school or work) in sedentary behaviours” (Tremblay et al., 2017, p.9). SB is distinct from “physical inactivity”, which is defined as “an insufficient physical activity level to meet present physical activity recommendations” (Tremblay et al., 2017, p.9), but the two terms are often incorrectly used interchangeably (Sedentary Behaviour Research Network, 2012).

2.3.2 Stationary behaviour

Unlike SB, stationary behaviour is not restricted to a specific posture or energy expenditure, as it includes any waking behaviour, in any posture, with no ambulation irrespective of energy expenditure (Tremblay et al., 2017). Hence, it encompasses all SBs as well as behaviours like standing still in a queue or standing while playing/talking on a mobile phone.

2.3 Sedentary behaviour guidelines

The increased volume of research over the last two decades focussing on SB and its relation to ill health (LeBlanc et al., 2012; Carson et al., 2016a), the determinants of SBs (Stierlin et al., 2015) and interventions to reduce SB in children (DeMattia, Lemont and Meurer, 2007), has led to the inclusion of recommendations regarding SB in many national public health campaigns and guidelines documents. Australia (Department of Health, 2019) and Canada (Tremblay et al., 2016b) both have 24-hour movement guidelines, including recommendations for PA, SB and sleep. They recommend that children limit their recreational screen time to no more than two hours per day, and avoid sitting for extended periods of time. The UK government guidelines for children and young people aged 5-18 years are more generic and non-quantitative, recommending that children "should aim to minimise the amount of time spent being sedentary, and when physically possible should break up long periods of not moving with at least light physical activity" (Department of Health and Social care, 2019, p.9). The United States Department of Health and Human Services does not mention SB in their PA guidelines for children (U.S. Department of Health and Human Services, 2018).

While some researchers are urgently calling for public health guidelines to include quantitative targets set to reduce SBs, arguing that setting such targets are low risk and important for public health (Chaput, Olds and Tremblay, 2018), others feel it would be premature as the SB evidence base is still too weak to inform any specific quantitative guideline (Stamatakis et al., 2019a). Despite the wealth of SB-related research published over the last decade, Stamatakis et al. (2019a) argue that the evidence is underdeveloped and (amongst other issues) relies too heavily upon self-report measures, which are known to underestimate ST. The authors state that premature quantitative guidelines on SB can potentially be harmful to public health, as once established they are difficult to change without creating confusion.

2.4 Sedentary behaviour and related health risks

The wide range of health benefits associated with PA are well established (Janssen and LeBlanc, 2010; Poitras et al., 2016). Less is known about the association between SB and health indicators, mainly due to the complex nature of the behaviour and the lack of standardised methods able to capture it accurately. In fact, as recently as 2008, Pate, O'Neill and Lobelo (2008) pointed out that many studies at the time drew conclusions about the health effects of SB *without actually measuring SB*. Since then, researchers have started to include SB or ST as an outcome measure, instead of merely labelling those participants not meeting PA guidelines as 'sedentary'.

Results from one large cross-sectional study, combining accelerometer data from multiple cohorts (n = 20871, 4-18 year olds) showed no relationship between ST and cardiometabolic risk factors, after adjusting for MVPA (Ekelund et al., 2012). In another cross-sectional study (n = 2527, 6-19 year olds), examining the relationship between the volumes, patterns and types of SB with cardiometabolic risk in children, Carson and Janssen (2011) found no relation between volumes or patterns of SB with risk. However, *types* of SBs seemed to be important, as increased amounts of TV viewing were positively associated with cardiometabolic risk, while computer use showed no associations. Carson and Janssen (2011) offer possible explanations for this finding, including the fact that TV viewing is associated with a higher exposure to junk food advertisements (compared to other screen-based behaviours), which in turn encourages between meal snacking. Secondly, the authors suggest that TV viewing might be at the lowest end of the energy expenditure spectrum, in other words children use less energy while watching TV compared to other screen-based behaviours.

A systematic review of 232 studies in 2011, found 2 hours of SB per day to be associated with an increased risk of obesity, decreased fitness, low self-esteem, lowered pro-social behaviour as well as decreased academic achievement (Tremblay et al., 2011). However, the majority of the studies included in the review assessed SB by TV viewing alone. Therefore, an updated review of 235 studies was published in 2016 (Carson et al., 2016a) that included more types of SBs, e.g. computer use, video games, reading and homework. The authors found that different types of SBs had different associations with health indicators. While increasing amounts of TV viewing was found to be unfavourably associated with all health indicators (consistent with the previous review), inconsistent associations were found between computer and video game use. Reading and homework were, perhaps as may be expected, found to be positively associated with academic achievement. During a cross-sectional study investigating the effect of SBs on the mental well-being of adolescents (n = 1296, 12-17 year olds), Suchert et al. (2015) found that high amounts of screen time had a detrimental effect on girls' but not boys' mental health indicators (i.e. self-esteem, physical self-concept and general self-efficacy). Similarly, Shakir et al. (2018) found different types of SB to have different associations with adiposity in boys than in girls (n = 234, 10-13 year olds). Therefore, not only is it important to distinguish between *types* of SB, but also SBs seem to have different health implications for boys and girls.

Results from both the Tremblay et al. (2011) and Carson et al. (2016a) reviews should be considered with caution, as they mostly included studies that failed to use reliable and valid methods of measuring SB. Carson et al. (2016a) concluded that the quality of evidence in four of their six health indicators investigated were 'very low', mainly due to serious risk of bias present. Similar conclusions were drawn by Stiglic and Viner (2019), who conducted a systematic review of reviews on the effects of screen time on the health and well-being of children and adolescents. Thirteen reviews were identified, including one of high quality, nine medium quality and three low quality reviews. While the majority of studies focussed on TV viewing, data from other forms of screen time like computer use, video games and mobile phone use were sparse. The authors felt the evidence base was too weak to identify a threshold for safe screen use. Conversely, results from a study not included in the mentioned review of reviews (Fang et al., 2019), found positive correlations between overweight/obesity and total screen time, TV viewing and computer use. This review included 16 studies, with 14 considered to be of moderate to high methodological quality. While there is an established negative association between TV viewing and health markers, evidence regarding the health risks of other forms of screen time is weak, perhaps not because of lack of associations between outcomes, but potentially due to a lack of studies using robust methods to measure SBs.

2.4.1 Is sedentary behaviour an independent health risk factor?

SB has received increased attention as an independent health risk factor, with many studies suggesting that SB contributes to a number of health-related conditions in children and adults, *independent of PA* (e.g. Salmon et al., 2011; Van der Ploeg et al., 2012). In adult studies it is often argued that a person can be highly active (exceeding the government guidelines), but at the same time spend most of the day engaged in SB, for example sitting at a desk in an office.

While there is an established association between SB and all-cause mortality in adults (Van der Ploeg et al., 2012), a harmonised meta-analysis of more than 1 million participants showed that PA weakens and even eliminates the detrimental effects of SB (Ekelund et al., 2016), with Stamatakis et al. (2019b) confirming this finding. However, PA only eliminated the negative effect of SB in the most active quartile of the population. While these findings were based on results from self-report data, a similar study using accelerometer data (n = 36383) concluded that ST and all intensities of PA were associated with all-cause mortality in adults in a dose-response manner (Ekelund et al., 2019). The authors observed maximal risk reductions at lower PA levels and slightly higher ST compared with the previous, self-reported data. In other words, contrary to the self-report results, small increases in PA reduced the risk associated with being sedentary. It is clear from these findings that the two behaviours interact, therefore cannot and should not be examined separately when investigating health risks, as PA modifies the association between ST and health in adults.

Even though there is a lack of similar, large-scale studies in children, smaller studies have reached this same conclusion, that MVPA attenuates the association between ST and health risks (Steele et al., 2009; Ekelund et al., 2012; Noonan et al., 2019; Wijndaele et al., 2019). However, evidence is slowly accumulating to suggest that certain types of SBs (especially various forms of screen time) are associated with obesity, cardiometabolic risk and mental health issues in children (Ekelund et al., 2006; Danielsen et al., 2011; Twenge et al., 2017; Fang et al., 2019). These findings cannot be ignored, as large numbers of children do not meet the recommended PA guidelines (Ekelund et al., 2012) and therefore do not receive the risk reduction afforded by reaching the recommended volumes of MVPA. Steele et al. (2009) therefore states that strategies to target both low levels of PA and high levels of SBs should be employed in order to gain the health benefits of increased PA and to alleviate the mental health issues associated with high amounts of screen time.

2.5 Levels of sedentary behaviour

Reporting on the current prevalence of SB in children is challenging, as few studies have used the same methods to measure the behaviour, therefore complicating comparisons between studies. While some studies only report on certain types of SBs like TV viewing or screen time (e.g. O'Brien, Issartel and Belton, 2018), others chose to focus on specific time periods like after school SBs (e.g. Arundell et al., 2016) or during school break times (e.g. Greca and Silva, 2017). Although many studies use minutes per day as their outcome measure (from either self-report or accelerometer data), some report on the number of children spending less or more than two hours in front of screens per day (e.g. Atkin et al., 2014), while others choose to report ST as a percentage of accelerometer wear time (e.g. Spittaels et al., 2012).

The Global Matrix 3.0 initiative recently published PA report cards from 49 countries worldwide, reporting on 10 indicators, one of which was SBs (Aubert et al., 2018). The initiative is led by the Active Healthy Kids Global Alliance, who appoints a mentor to each participating country, ensuring adherence to the harmonisation processes (Tremblay et al., 2016a). Each country in turn appoints a group of researchers or experts to gather the best and most recent evidence to report. The development and release of report cards have been used in many countries as an advocacy and social mobilisation tool (Tremblay et al., 2016a), hoping to increase children's PA levels. The results, mainly based on data from national surveys, are presented as grades ranging from A+ (94 - 100%) to F (< 20%). SB is defined as the percentage of children who meet the Canadian SB guidelines of no more than 2 hours of recreational screen time per day. The recently published (Aubert et al., 2018) SB grades ranged from F (China, Estonia, Ethiopia, Wales and Scotland) to A- (Bangladesh), with England scoring the same as the overall average of D+. Lower income countries scored better on average than high income countries (C+ vs D+), but the authors warned that economic growth and development of low income countries will lead to increased access to screen-based devices, implying that it is only a matter of time before the same high levels of screen time is observed in the children of low income countries. While these grades allow for easy comparison between countries, Tremblay et al. (2016a) points out that the quality and quantity of the evidence vary substantially across participating countries.

In 2012, Ekelund and colleagues published the results of 20871 children (4-18 years old) from Australia, Brazil, the United States and Europe, according to waist-worn ActiGraph data obtained through the International Children's Accelerometer Database (ICAD) (Ekelund et al., 2012). On average boys spent 345 min/day (SD=96) sedentary and girls 363 min/day (SD=96). These studies, however, were conducted between 1998 and 2009. A couple of years later, albeit from a much smaller study in Canadian children wearing Actical accelerometers on the hip (n = 1608, 6-19 years old), Colley et al. (2013) reported boys to spend 508 min/day (SD=91) and girls 524 min/day (SD=92) sedentary. Even though slightly outdated, these results are consistent with data from the ICAD (Cooper et al., 2015), i.e. from the same dataset (n = 27637, 3-18 year olds) as the above-mentioned Ekelund study, but reporting that ST of girls are consistently higher than boys, and that ST increases with age. These studies all defined ST as the amount of time spent below 100 accelerometer counts per minute, and did not consider the postural component of the behaviour.

A more recent accelerometer-based study in UK children confirmed that ST increases with age. Noonan et al. (2019) reported 9-10 year olds (n = 93) to spend 581 min/day (SD=108) sedentary, compared to 672 min/day (SD=113) in 94 12-13 year olds and 726 min/day (SD=115) in 105 14-15 year olds. These results are from data obtained via SenseWear Armband Mini devices, which are accelerometers worn on the upper arm. During the same cross-sectional study, participants' self-reported data showed that with increasing age, children were more likely to spend more time playing video games, using a computer / tablet and using a mobile phone. In one of a few studies found in the literature using activPAL to report sitting time in children, the 9-10 year old participants spent on average 614 min/day (SD=112) seated on weekdays and 691min/day (SD=150) on weekend days (Sherry et al., 2018). This was, however, from a small sample (n=79).

The different methods used to measure SB makes it difficult to compare studies. Even between accelerometer-based studies, researchers use different methods to process and analyse the data (e.g. different accelerometer brands, different thresholds to define ST, different non-wear and inclusion criteria etc.), resulting in findings that are impossible to directly compare. Therefore, it is difficult to gain a clear picture of how much time children spend in SBs.

2.6 Determinants of children's sedentary behaviours

Knowledge of the correlates and determinants of SB is essential to the development of future interventions aiming to reduce SBs. Correlates refer to cross-sectional associations between variables and SBs, while determinants are causal factors identified through longitudinal studies (Bauman et al., 2002). Evidence of the factors influencing children’s SBs are sparse. One systematic review of longitudinal studies (n = 30 studies; 7 considered high quality) investigating the determinants of PA and SB in 4-18 year olds, found insufficient evidence regarding the determinants of SB (Uijtdewilligen et al., 2011). Other reviews have mainly focussed on individual factors affecting children’s SBs (Pate et al., 2011; Stierlin et al., 2015).

A review by Pate et al. (2011) (n = 76 studies) grouped the factors determining children’s SBs into the following five categories: demographic, biological, psychosocial, behavioural and environmental, while Stierlin et al. (2015) structured their review of 37 studies around the ecological model of SB, placing the individual within an ecosystem (Owen et al., 2011). Their model differentiates between individual, interpersonal, environmental and policy level determinants. Both reviews found age and ethnicity to be determinants of SB, with screen time as well as total ST increasing with age, and higher levels reported in non-white children. Gender, socioeconomic status and weight status produced inconsistent evidence. Eating in front of the TV or screen was found to be a determinant of higher levels of screen time in both reviews. Stierlin et al. (2015) found youth with more depressive symptoms to spend more time in front of screens, while Pate et al. (2011) reported children who actively travelled to school spent less time in SBs. While the Pate review did not report on the methodological quality of their studies, the majority of studies included in the Stierlin review were considered to be of good quality. Consistent with these findings, Uijtdewilligen et al. (2011) observed variation in SB at the individual level and a lack of evidence concerning the social and environmental domains.

In a longitudinal study by Atkin and colleagues, the authors investigated the determinants of a three-year change in accelerometry-based ST, specifically focussing on social, psychological and environmental determinants (Atkin et al., 2016). Over three years, from age 11 to 14, after-school as well as weekend ST increased by approximately 30-40 minutes per day. Of the 14 variables investigated, only one, i.e. active transport, remained significant in their final multivariable model. Children who cycled to school showed smaller increases in after-school ST over a three year period.

2.7 Sedentary behaviour measurement

Valid and reliable methods to assess SB in children are crucial, whether studies aim to understand the relationship between SB and health, identify correlates and determinants of SB, monitor population health or evaluate the impact of interventions. Numerous methods have been used to measure SB, but reviews by Lubans et al. (2011) and Hidding et al. (2017) highlighted the poor validity and reliability of these existing methods.

2.7.1 Self-report

2.7.1.1 Questionnaires

Subjective measures like self-report questionnaires and surveys are the most commonly reported methods of estimating SBs (Atkin et al., 2012). In a recent systematic review of self-report and proxy-report questionnaires assessing children's SBs, Hidding et al. (2017) identified 46 different questionnaires. These include proxy-report questionnaires for younger children (mean age < 6 years) e.g., the Preschool-aged Children's Physical Activity

Questionnaire (Pre-PAQ) and KidActive-Q, questionnaires for children aged 6-12 years e.g. the Sedentary Behaviour and Sleep Scale (SBSS) and the Youth Activity Profile (YAP), as well as questionnaires for adolescents e.g. the Adolescent Sedentary Activity Questionnaire (ASAQ) and the International Physical Activity Questionnaire (IPAQ). The number of questions regarding SB range from as little as one or two (e.g. SBSS with 2 questions) to 91 domain-specific questions in the ASAQ. The latter differentiates between five domains, i.e. screen recreation, educational, cultural, social and transport (Guimarães et al., 2013). Nineteen questionnaires focussed only on screen time, while 24 questionnaires covered a variety of constructs of SB. Recall periods ranged from previous day, previous week, a typical day/week to the previous month.

Traditional pen and paper-based self-report tools (or proxy-report in the case of younger children) are inexpensive and easy to use, therefore suitable for studies involving large sample sizes, but perhaps their greatest strength is their ability to capture contextual data like the types of SBs children engage in (Hardy et al., 2013). However, self-report tools also have significant limitations. They rely on participants to recall behaviours accurately, and the ubiquitous nature of SB ("unremarkable, intermittent and incidental" (Atkin et al., 2012, p.1467)) makes this especially difficult, even for adults. Measurement error due to recall errors, deliberate misrepresentation and social desirability (Hardy et al., 2013) is most likely responsible for self-report tools being known to overestimate PA (Adamo et al., 2009) and underestimate SBs (Affuso et al., 2011). Conversely, some domain-specific questionnaires have been found to overestimate ST in both adults (Wijndaele et al., 2014) and adolescents (Busschaert et al., 2015). Both studies conclude that the inclusion of multiple contexts, e.g. TV viewing, mobile phone use, computer use etc. likely resulted in double-reporting of ST due to simultaneous behaviours. For example, a child might be watching TV while simultaneously spending time on a mobile phone and then reporting both behaviours as if they occurred separately.

In an attempt to overcome the measurement error associated with self-report tools, researchers have calibrated self-report questionnaires against accelerometry (a direct assessment of PA and ST) (Saint-Maurice et al., 2014; Saint-Maurice and Welk, 2015). In a recently published UK-based study, Fairclough et al. (2019a) calibrated the Youth Activity Profile (YAP) against accelerometer data obtained from SenseWear armband mini devices. The resultant UK YAP algorithm produced estimates of out-of-school SBs that were equivalent on average at the group level to within a 15% of the SenseWear estimates. While the UK YAP shows promise as a future surveillance tool to capture both PA and SB, its authors concluded that added work is needed with a more representative sample, to refine the algorithm and increase classification accuracy. In addition, the YAP only estimates out-of-school SB, whilst there is a need to also capture weekend- as well as total SB.

Despite the many self-report questionnaires currently available, the authors of the Hidding et al. (2017) review felt they were unable to recommend the best available self-report tool for researchers to use, due to the poor methodological quality of most questionnaires included in their review.

2.7.1.2 Use-of-time tools

Self-report use-of-time tools require children to recall their PA and SB in a structured, chronological order over specific time periods (Foley et al., 2012). A number of use-of-time tools are available in the literature, with children typically required to recall either the previous day or the last three days, in specific time slots, thus accounting for the full 24-hour day (Foley et al., 2012). Some of these tools are computerised, for example the Multimedia Activity Recall for Children and Adolescents (MARCA) (Ridley, Olds and Hill, 2006) and the Computerised Activity Recall (CAR) (McMurray et al., 1998). The MARCA asks children to report their previous day in intervals of 5 minutes or greater, while the CAR uses intervals with a minimum of 15 minutes. For both tools, children have to choose from a list of 200 activities. Foley et al. (2012) points out that there is a trade-off between resolution and participant burden for all use-of-time tools. Recalling short intervals like 5 minutes might be difficult for children, but longer time periods might not capture the full range of children's activities. While most use-of-time tools have indicated moderate validity for assessing PA, few have validated their SB component (Foley et al., 2012).

2.7.1.3 Ecological Momentary Assessment

Ecological Momentary Assessment (EMA) includes a range of methods that capture self-report data in real-time. First introduced in 1994 by Stone and Shiffman (1994), these methods use repeated assessments (as often as every 30 minutes), thus capturing behaviours in real-time and in participants' natural environments (Shiffman, Stone and Hufford, 2008). Unlike questionnaires and use-of-time tools, EMA does not rely on retrospective recall and claims to reduce bias and errors associated with recall (Smyth and Stone, 2003). While older studies used traditional pen and paper diaries (Marszalek et al., 2014), more recent studies have mainly employed mobile phone applications for data collection (Romanzini et al., 2019). A strength of EMA is its potential to capture contextual information. For example, Liao et al. (2014) investigated the physical and social contexts of 9-13 year old children's non-school SBs. Mobile phones prompted participants to complete a total of 20 surveys across four days, measuring current activity, physical location as well as social company. After conducting a systematic review of the methodologies used in EMA studies, Romanzini et al. (2019) recommend that using EMA with mobile phones, in combination with accelerometry is the best method to capture SBs. However, this method will exclude children who do not own mobile phones, and assessments would be restricted to out-of-school time, as mobile phones are typically not allowed in school classrooms.

2.7.1.4 Creative self-report methods to capture qualitative data

Collecting data from children requires "a special approach", often involving multiple methods (Porcellato et al., 1999; Greig, Taylor and MacKay, 2007). Child-centred methods like draw and write, during which the child is asked to draw a picture and write something about their picture, are often used in research to explore children's beliefs about health behaviours (Pridmore and Bendelow, 1995; MacGregor, Currie and Wetton, 1998; Knowles et al., 2013). It enables children to express their feelings and views at their own levels of cognitive development (Knowles et al., 2013) and simulates an activity that they are comfortable and familiar with (Porcellato et al., 1999). Noonan et al. (2016b) evolved this method by adding a show-and-tell element and using his write, draw, show and tell method effectively while exploring children's perceptions of out-of-school PA. The use of the draw and write method to capture children's SBs has not been reported in the literature.

Another creative way of capturing contextual information is through photographs. Wang and Burris (1997) calls this method *photovoice*, a tool for participatory research. It involves giving cameras to participants and asking them to record images of their communities or surroundings thus enabling researchers to see data captured through the eyes of their participants. The method recognises that people have insights into their own worlds that professionals lack (Wang and Burris, 1997), and is typically used in populations who have little power, money or status (Strack, Magill and McDonagh, 2004). It gives people, who would typically be excluded from decision-making processes, a 'voice' by capturing important aspects of their lives (Foster-Fishman et al., 2005). It has been used in varied populations, like rural Chinese women (Wang and Burris, 1994), homeless adults (Wang, Cash and Powers, 2000) and Aboriginal youths (McHugh, Coppola and Sinclair, 2013). More recently, Gullon et al. (2019) used photovoice to examine environmental factors associated with PA in adults, while Heidelberger and Smith (2016) employed photovoice in 9-13 year old urban children from low-income homes, to gain insight into their PA habits. Photos from the latter study identified media (screen-based) related activities as a barrier to PA. Results further revealed that family and peers played an influential role in the participants' PA, while the physical environment (outdoor versus indoor) also determined levels of PA.

2.7.2. Accelerometry

Accelerometry is viewed as a valid method to objectively assess children's free-living ST (Lubans et al., 2011; Atkin et al., 2012). Traditionally used to measure PA (Hardy et al., 2013), accelerometers capture the frequency and amplitude of acceleration of the body part to which they are attached. Thus, very little or a lack of movement is usually classified as ST. The advantages of using accelerometers include their unobtrusiveness, ease of use and the fact that they are not reliant on children to accurately recall behaviour (Rowlands, 2007). While accelerometers are expensive, they can be redeployed and used repeatedly, thus reducing the cost of subsequent studies. Accelerometers have limitations as well. Even though participants might find them easy to use, processing and analysing accelerometer data requires researcher expertise. Most accelerometers are unable to differentiate between postures, a requirement vital for SB measurement. GENEActiv and ActiGraph wrist accelerometers can predict a person's most likely posture (sit or stand) through a method known as the Sedentary Sphere (Rowlands et al., 2014), but this has not been validated in children. In addition, perhaps accelerometry's biggest limitation is the inability of the monitor to provide any contextual information, like the types of sedentary activities children engage in or where these activities take place.

2.7.2.1 Accelerometer brands and placements

A number of accelerometer brands are available, but ActiGraph, GENEActiv, Actical and Axivity are the most widely used in physical activity research (Rowlands, 2018; Rowlands et al., 2018b). While most brands can be placed either on the wrist or attached to the hip, studies in children have shown greater compliance with wrist-worn devices (Trost, Zheng and Wong, 2014; Fairclough et al., 2016), with children expressing fears of being bullied for wearing hip-worn monitors (McCann et al., 2016). A second possible reason for the longer wear times observed in studies using wrist-worn devices is that they can easily be worn while sleeping, therefore reducing the possibility of participants forgetting to wear their monitors on subsequent days after taking them off at bedtime. In addition, there is evidence that wrist-worn accelerometers provide better estimates of energy expenditure in children compared to those worn on the hip (Crouter, Flynn and Bassett, 2015). The activPAL, a thigh-mounted monitor able to distinguish between sitting/lying and upright postures, are most often used in adult SB studies (Edwardson et al., 2017). However, the few free-living studies in children that have used activPAL, have reported low compliance rates (e.g. 58%, Sherry et al., 2018) and a high number of participants removing monitors (40%) during 7 days of data collection (Shi et al., 2019). Participants mainly cited skin irritation and sweating as reasons for removing monitors, with 80% saying the 7-day wear period is too long and 55% stating they would not wear it again. More details about the specific monitors used during this body of research can be found in General Methods (Chapter 3, section 3.5).

2.7.2.2 Wear time criteria

The monitoring period for accelerometer-based assessments of SBs, similar to measuring PA, is typically seven days (Atkin et al., 2012). Inclusion criteria differs between studies, with no standardised protocols to guide researchers. In PA research, a minimum wear time of ≥ 10 hours per day is typically used for inclusion in analysis (Ridgers and Fairclough, 2011; Cain et al., 2013), however, longer wear time is needed when assessing ST (Kang and Rowe, 2015). Since the publication of the 2016 Canadian 24-hour movement guidelines that includes recommendations for sleep (Tremblay et al., 2016b), many researchers now record the full 24-hour day in order to report on all movement behaviours (i.e. sleep, SB, LPA and MVPA), with several choosing a minimum of ≥ 16 valid hours per day as inclusion criteria (e.g. Rowlands et al., 2016b; Fairclough et al., 2017).

Participants with a minimum number of valid days, typically ranging from 3-5 days, would then be included in further analysis (Atkin et al., 2012). While fewer number of days will result in more participants included, it reduces the validity and reliability of the data (Ridgers and Fairclough, 2011). Trost et al. (2000) reported that 4-5 days of children’s data are necessary to achieve 80% reliability of ST estimates, with Basterfield et al. (2011) confirming these findings. Their results showed a minimum of 3 days provided 73% reliability.

2.7.2.3 Accelerometer data analysis

There are various ways to process and analyse accelerometer data and no standardised protocol for researchers to follow. While the threshold-approach is still the most commonly used method in the literature, new cut-point free accelerometer metrics have recently been published.

2.7.2.3.1 Thresholds

In order to give behavioural meaning to accelerometer data, researchers have attempted to calibrate accelerometer output with energy expenditure, by publishing thresholds (also called cut-points) related to different movement intensities. These thresholds allow researchers to calculate time spent in various categories of energy expenditure e.g. ST and MVPA.

Until 2010, accelerometer output was reduced to 'counts' by device-specific manufacturer software, using proprietary algorithms (Rowlands, 2018). Comparing data collected by different accelerometer brands was not possible, due to differences in how the raw data were collected, processed, filtered and scaled (Welk, McClain and Ainsworth, 2012). Various calibration studies produced a variety of thresholds, which enabled researchers to convert 'counts' to estimates of time spent in different PA intensities (e.g. Evenson et al., 2008; Hänggi, Phillips and Rowlands, 2013; Chandler et al., 2016). However, this further complicated comparability between studies as large variations in activity outcomes were recorded depending on which cut-points are selected for analysis (Rowlands, 2018).

More recently, researchers recommended that data be stored as raw signals and data transformation be carried out post-processing (Freedson et al., 2012; Welk, McClain and

Ainsworth, 2012), in order to facilitate comparisons between studies and give researchers control over the decision making process. Accelerometer manufacturers like ActiGraph, GENEActiv and Axivity have since developed devices that are able to capture raw, unfiltered accelerations in three axes (x, y and z) (Rowlands et al., 2016b; Rowlands, 2018) at sampling frequencies of up to 100 Hz for ActiGraph and GENEActiv, and 1600 Hz for Axivity monitors. Accelerations are expressed in gravity (*g*) units and researchers typically use software like R or MATLAB for data processing, which includes calculating Signal Vector Magnitudes (SVM) from raw x, y and z acceleration signals and extracting PA variables from the raw data files. Access to raw data increases researcher control over data processing and, in theory, raw data from different accelerometer brands should be equivalent. Very high agreement in reported minutes spent in MVPA has been recorded between ActiGraph and GENEActiv monitors (intraclass correlation coefficient = 0.98), however, small differences were observed in the lower acceleration ranges indicative of ST, suggesting technical differences between the two brands and/or proprietary on-board processing of raw data by ActiGraph (Rowlands et al., 2016b).

When using the threshold-approach, raw data analysis is still reliant on calibration studies to produce cut-points. In recent years, studies have published raw acceleration sedentary thresholds for children (Phillips, Parfitt and Rowlands, 2013; Schaefer et al., 2014; Aittasalo et al., 2015; Hildebrand et al., 2016). Data collection protocols and data reduction methods differed between these studies, again complicating comparisons between results. Of these, only Hildebrand et al. (2016) used the Euclidean norm minus one (ENMO) metric, a method of calculating the SVM that does not rely on sampling frequency and should allow for easier comparisons between studies. The ENMO metric also removes the gravitational component of the acceleration signal by subtracting one gravitational unit from the Euclidean norm (vector magnitude) of the 3 raw signals (van Hees et al., 2013). By doing so, only accelerations due to movement are reported. The sedentary thresholds developed by Hildebrand et al. (2016), however, did not perform well in a free-living sample compared with data from activPAL. All their thresholds (from non-dominant wrist- and hip placements of ActiGraph and GENEActiv) significantly overestimated ST according to activPAL, except for their ActiGraph wrist threshold of 35.6 m*g*. However, Bland-Altman analysis showed that its mean bias (+30) and limits of agreement (-226 min to +287 min) were large. A possible explanation for their thresholds' limited accuracy during free-living is that their study protocol included only two sedentary activities (sitting and lying), thus not representative of the wide range of SBs children engage in.

2.7.2.3.2 New accelerometer metrics

In order to avoid what has been called the "cut-point conundrum", Rowlands (2018) proposed the use of two accelerometer metrics. The first is "average dynamic acceleration" or just "average acceleration". It refers to acceleration due to movement, corrected for gravity (Rowlands, 2018), and can be used as a single measure of the volume of activity (expressed in milli (10^{-3}) gravity-based acceleration units (m*g*), averaged per day). The second metric is called "intensity gradient" (IG). The IG is a reflection of the intensity profile of an individual (Rowlands et al., 2018a). Plotting the natural logs of time accumulated against acceleration intensity results in a straight-line (negative slope) graph. A steep, more negative gradient reflects a poorer intensity profile, with the person spending more time in the low- to mid-range intensities, while a shallow, less negative (higher) gradient shows more time is spent in higher intensities (Rowlands et al., 2018a). The latter person, therefore, has a more favourable intensity profile.

Fairclough et al. (2019b) examined the association of these two metrics with health and well-being indicators in children, and found IG to be significantly associated with obesity indicators, metabolic risk and cardiorespiratory fitness, independent of average acceleration. Average acceleration, on the other hand, was associated with health-related quality of life, independent of IG. Unlike thresholds, these two metrics are easily comparable between studies and monitors. However, they are not easily interpretable and translating it to public health messages might prove challenging.

Another alternative accelerometer outcome variable, the acceleration above which a person's most active minutes are accumulated, has recently been proposed by Rowlands et al. (2019). For example, the metric can identify the minimum acceleration above which a child's most active 60 minutes ($M60_{ACC}$) of the day are accumulated. This metric is not population-specific and, like average acceleration and IG, easily comparable between studies using different monitors. Its focus, however, is PA and does not tell us anything about sedentary time.

Accelerometry has often been described as an objective method of measurement as participants are not required to report their own PA and SBs, however, the researcher decision-making required during data processing and analysis brings its objectivity into question. The new accelerometer metrics shift most of these decisions to post-processing, enabling comparability between studies. While these metrics solve many of the issues related to the threshold approach, they are not as easily translated to the public as e.g. minutes spent in different intensities. They reflect the whole activity profile in one outcome variable, without focussing on just one intensity like MVPA, ST or sleep. While public health guidelines still focus on time spent in various intensities, researchers need to report these as accurately as possible. The advantage of using raw data though, is that these metrics, together with the threshold approach, can simultaneously be produced using the open-source R-package GGIR. The use of GGIR is discussed in more detail in Chapter 3 (General methods).

2.7.3 Direct observation

Direct observation (DO) is the only tool with the potential to capture total volume of SBs, the different types of activities as well as added contextual details. Context could be that of the settings in which the behaviour takes place or whether the child is alone or interacting with others. DO has successfully been used in restricted spaces during short periods of time, e.g. school playgrounds during break time / recess (Roberts et al., 2013). While DO has proved to be a valid and reliable method of measuring children's SBs (Lubans et al., 2011), it is not without limitations. DO is labour intensive, therefore expensive and not feasible to measure habitual SBs over a 7-day period. It can only be used in small samples, and subject reactivity is also a concern (Lubans et al., 2011).

Wearable cameras have been used in adult studies as a criterion measure of a DO proxy. Kim and Kang (2019) validated their use-of-time tool, the Sedentary Behaviour Record (SBR), by asking participants to wear a camera attached to a lanyard around their necks, capturing two automated hands-free images per minute. These time-stamped images served as a proxy of DO (Kim and Kang, 2019). Using wearable cameras for capturing habitual SB of children, however, introduce considerable ethical concerns. Automatic image capturing will invariably result in images of third parties (e.g. other children) who did not consent to their pictures being taken (Kelly et al., 2013). In addition, a lanyard around a child's neck might be considered a safety risk on a busy playground / schoolyard. Participant burden should also be considered, as limited battery life means cameras have to be charged daily.

Despite the variety of measurement tools currently available, no single tool is able to capture and describe children's habitual SBs comprehensively. The strength of most subjective tools lies in their ability to capture contextual data, for which accelerometers are incapable of doing. On the other hand, one of the weaknesses of self-report tools is their resultant measurement error due to recall bias, while accelerometry benefits from not relying on accurate recall of behaviours. Therefore Lubans et al. (2011) recommends that a *combination* of self-report and more direct measures (like accelerometry) be used when aiming to capture children's SBs, presenting a gap in the literature.

2.8 Summary

The literature review has highlighted that research into children's SBs is still in its infancy. Consensus definitions related to SB have recently been published (Tremblay et al., 2017), but the levels of children's SBs and clear links to its relationship with health outcomes in children remain largely unknown. None of the phases of research in this field, as outlined by the behavioural epidemiology framework (Owen et al., 2010), can advance much further without more consistent, valid and reliable methods used to assess SB. This thesis aims to address this gap in the literature, by focussing on assessing children's SBs more accurately.

CHAPTER 3

GENERAL METHODS

3.1 Introduction

The purpose of this chapter is to describe the general methods used during data collection and analyses throughout this body of research. Where needed, more specific details about each study's procedures are covered in the methods sections of the relevant chapters. All studies received ethical approval from the Research Ethics Committee of Liverpool John Moores University (reference numbers for Study 1 and 2: 16/SPS/056, Study 3: 17/SPS/034 and Study 4: 18/SPS/030, see Appendix I). The lead researcher was present at all data collection sessions, assisted by one or two trained research assistants.

3.2 Recruitment

Primary schools in Liverpool and Widnes (North West England) were contacted via e-mail and invited to participate in studies 1 to 3. Gatekeeper consent was obtained from all schools who responded to the e-mail and expressed an interest in participating. Information packs were provided to schools for distribution to all Year 5 children. These included information sheets for parents / carers (referred to as parents herein), age-appropriate information sheets for children (see Appendices A – D), parent informed consent and child assent forms as well as demographic information forms (Appendix E). Signed consent and assent forms were obtained from all participants prior to any data collection. Response rates are detailed in each individual study chapter.

3.3 Demographic information

Parents of child participants in Studies 1 to 3 completed demographic information forms, reporting their children's dates of birth, ethnicity and home postcodes. Socio-economic status (SES) was calculated using the UK Government 2015 Indices of Multiple Deprivation (IMD) (Ministry of Housing Communities and Local Government, 2015). The National Statistics Postcode Directory was used to generate IMD rank scores and their corresponding IMD decile scores, from home postcodes. IMD decile scores range from one to 10, where one represents the most deprived and 10 the least deprived 10% of areas nationally.

3.4 Anthropometric measurements

Anthropometric measurements were completed by either the lead researcher or a research assistant using standard methods as described by Lohman, Roche and Martorell (1991). All measurements were taken twice, the means calculated and recorded. In cases where there were more than 1% difference between the two measurements, a third measurement was taken and the median of the three measurements recorded. Body mass was measured in light clothing without shoes, to the nearest 0.1 kg using electronic scales (Seca, Birmingham, UK). Stature and sitting height were measured to the nearest 0.1 cm using a portable stadiometer (Leicester Height measure; Seca, Birmingham, UK). 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). Participants self-reported their dominant hand.

Sex-specific regression equations (Mirwald et al., 2002) were used to predict children's age at peak height velocity (APHV), which is a proxy measure of biological maturation using stature, sitting height, body mass and decimal age information. Participants' APHV are reported in studies 1 and 3 in an effort to describe the sample as accurately as possible. The equations used are presented below:

Boys:

Maturity Offset = -9.236 + [0.0002708 x (leg length x sitting height)] + [-0.001663 x (age x leg length)] + [0.007216 x (age x sitting height)] + [0.02292 x (body mass by stature ratio)].

Girls:

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

3.5 Accelerometers

Accelerometers were used in studies 1 to 3. Three devices were used, namely GENEActiv (Studies 1 and 2), ActiGraph GT9X Link (Studies 1 to 3) and ActiGraph GT3X (Study 1). The GENEActiv (ActivInsights Ltd., Cambridgeshire, UK), ActiGraph GT9X Link and GT3X (ActiGraph, Pensacola, FL) are small, lightweight tri-axial accelerometers with a dynamic range of ±8 g. For each study, monitors were initialised with a sampling frequency of 100 Hz. While the ActiGraph GT9X Link looks like a watch and shows the time, it is more appealing to wear on the wrist than the slightly bigger, more cumbersome ActiGraph GT3X that is more suitable for the hip placement.

The activPAL (PAL Technologies Ltd., Glasgow, UK) was used in Studies 1 and 2 and is a small, single-site lightweight activity monitor that uses proprietary algorithms to classify an individual's free-living activity into periods spent sitting, standing and walking. It collects data at a sampling frequency of 20 Hz.

3.6 Accelerometer data processing and reduction

GA data were downloaded using GENEActiv PC software version 3.1 and saved in raw format as binary files. ActiGraph data were downloaded using ActiLife version 6.13.3, saved in raw format as .gt3x files and converted to .csv files for data processing. ActivPAL data were downloaded using activPAL3 version 7.2.32, saved as .datx files and converted to .csv event files for processing.

Signal processing of GENEActiv .bin files and ActiGraph .csv files was completed using the open source R-package GGIR (Migueles et al., 2019). Calibration protocol data from Study 1 were processed using GGIR version 1.5-17, while free-living data were processed using version 1.5-24. Version 1.6-7 was used to process data from Study 3. GGIR converts the raw tri-axial acceleration values from GENEActiv and ActiGraph into one omnidirectional measure of body acceleration corrected for gravity using the ENMO metric (van Hees et al., 2013), with negative values rounded up to zero. The ENMO metric is sensitive to poor calibration (van Hees et al., 2013); however, GGIR autocalibrates the raw tri-axial accelerometer signal in order to reduce the calibration error (van Hees et al., 2014). Autocalibration was carried out for free-living data, but not for the calibration protocol where data were collected over a short period of time precluding the use of autocalibration.

For free-living data from Study 3, GGIR detected periods of non-wear as described in supplementary document to van Hees et al. (2013). In short, GGIR calculates wear times for 60-

minute windows with 15-minute moving increments, based on the standard deviation (SD) and value range of each axis. A time window is classified as non-wear time if, for at least two out of the three axes the SD is less than 13 m*g* or the value range is less than 50 m*g*. The default non-wear setting was used, meaning GGIR imputes non-wear data by the average at similar time points on other days of the week.

Thesis study map

Study	Aims and key findings
Study 1: Establishing raw acceleration thresholds to classify sedentary and stationary behaviours in children	**Aims:** 1. To compare the raw accelerometer output of ActiGraph and GENEActiv accelerometers across different placements, 2. To identify raw acceleration signal thresholds for different sedentary behaviours in children, from both the hip and wrist, using ActiGraph and GENEActiv, 3. To validate the thresholds during free-living activities.
Study 2: Validating the Sedentary Sphere method in children.	
Study 3: Exploring a novel mixed-methods approach to assess children's sedentary behaviours.	
Study 4: Parental perceptions of the factors influencing children's sedentary behaviours.	

CHAPTER 4

STUDY 1

ESTABLISHING RAW ACCELERATION THRESHOLDS TO CLASSIFY SEDENTARY AND STATIONARY BEHAVIOUR IN CHILDREN

The main outcomes of this study have been published in *Children*: Hurter, L., Fairclough, S.J., Knowles, Z.R., Porcellato, L.A., Cooper-Ryan, A.M. and Boddy, L.M. (2018) Establishing Raw Acceleration Thresholds to Classify Sedentary and Stationary Behaviour in Children. *Children*, 5 (12).

4.1 Introduction

Accelerometers are widely accepted device-based methods of monitoring children's PA levels (Rowlands, 2007) and SB (Atkin et al., 2012). However, accelerometers have been found to both overestimate (Hart, McClain and Tudor-Locke, 2011) and underestimate (Kozey-Keadle et al., 2011) ST. Traditionally, researchers have used accelerometer output reduced to proprietary counts, but counts-based data limits comparisons between studies using different brands (Corder et al., 2008). PA intensity cut points derived from raw acceleration output have been developed for the GENEActiv and ActiGraph GT3X+ accelerometers (Hildebrand et al., 2014), making comparisons between these devices and placements (wrist and hip) possible (Fairclough et al., 2016) whilst also increasing researcher control over data processing. Although previous studies have attempted to establish raw ST thresholds (Esliger et al., 2011; Phillips, Parfitt and Rowlands, 2013; Schaefer et al., 2014; Aittasalo et al., 2015; Vähä-Ypyä et al., 2015; Bakrania et al., 2016; Hildebrand et al., 2016), none of these studies focused solely on children's ST, rather focusing on PA or adult populations.

Hildebrand et al. (2014) used Euclidean norm minus one (ENMO), a data reduction method which results in signal vector magnitude (SVM) values not dependent on sampling frequency or epoch length, allowing for easier comparison between studies. Hildebrand and colleagues have published ActiGraph and GENEActiv ENMO thresholds for PA (Hildebrand et al., 2014) and ST (Hildebrand et al., 2016) generated from a lab-calibration study. The sedentary thresholds were generated using two sedentary 'stations' (lying, watching television and sitting, using a computer) within a wider PA calibration protocol. The resultant thresholds were subsequently applied to free-living data but demonstrated low accuracy when compared with activPAL data (Hildebrand et al., 2016). One potential reason for the reduced performance during free-living activities was that the stations included within the circuit were not representative of the range of SBs that children engage in.

The present study applied the ENMO method to five sedentary activities representative of typical child behaviours. Data collection took place in the school gymnasium, mimicking a laboratory calibration study setting, but increasing the feasibility and ecological validity of the protocol involved. Furthermore, during a subsequent study, the thresholds were applied to free-living data and compared with data from activPAL as the criterion reference.

The aims of this study were: 1) to compare the raw accelerometer output of ActiGraph (AG) and GENEActiv (GA) accelerometers across different placements; 2) to identify raw acceleration signal thresholds for different SBs in children, from both the hip and wrist, using AG and GA; and 3) to validate the thresholds during free-living activities.

4.2 Methods

4.2.1 Participants

One primary school in Liverpool, England, was contacted via e-mail and invited to participate in the calibration study. After receiving gatekeeper consent, all Year 5 children (*n* = 60, 9-10-years-old) were invited to participate in the study. Completed informed parental consent and child assent forms were returned from 30 children (response rate 50%). Data collection took place on Mondays in January and February 2017, with two sessions per day (three participants at a time). On the last day of data collection, only one session took place, as the children were going on a school trip, therefore 27 children (17 girls) were included in the study. During a subsequent study (Study 3, Chapter 6), a subsample of 21 children (13 girls, 9-10- years-old) from two primary schools (in Widnes and Liverpool) were recruited to participate in the free-living study. Their data were collected between March and May 2018.

4.2.2 Anthropometrics

Anthropometric measurements were taken as described in General methods (Chapter 3, Section 3.4).

4.2.3 Sedentary behaviour

4.2.3.1 Calibration study protocol

Each participant was fitted with six accelerometers: one AG GT9X and GA monitor on each wrist (next to each other, in no specific or consistent order), an AG GT3X on the right hip and an activPAL monitor on the right anterior thigh. All monitors were worn throughout the testing protocol, which involved seven different stations representative of sedentary behaviour and light intensity physical activity (LPA) (see Table 4.1 for detailed description of the stations), with three participants rotating between the stations during each session. Before the standing with phone and sitting with tablet stations, participants were asked whether they were familiar with the games involved. All the participants knew the first game. Two participants were unfamiliar with the second game and were given time to familiarise themselves with it. The activities were performed for five minutes each, in no particular order except for TV viewing, which was always completed first in an effort to prevent the TV from distracting participants during the other activities. The stations were designed to simulate children's typical sedentary activities. Participants' start and end times for each activity were recorded with a Garmin Forerunner 235 wristwatch (synchronized with the same computer time used to initialise all monitors). The researchers observed the participants completing the stations (while standing a few meters away). After each session in the school gymnasium, the participants continued to wear the monitors for at least 10 minutes during school break time (also referred to as playtime). Participants were instructed to play as they normally would during break time, while the researchers observed and videotaped them from the side-line. The testing protocol lasted between 50 and 70 min per data collection session.

Table 4.1 Description of the seven SB and LPA stations

Station	Description
Resting	Lying on a soft gym mat, in a supine position, asked to avoid bodily movements.
TV viewing	Sitting comfortably on a couch, watching television.
Seated, tablet	Sitting comfortably on a couch, playing the Bike Race game on an iPad.
Seated, LEGO®	Sitting at a table, playing with LEGO®.
Seated, Homework	Sitting at a table, copying a piece of writing (mimicking homework).
Standing, phone	Standing while playing Subway Surf on a mobile phone.
Walking	Walking, at own pace, around a designated track.

4.2.3.2 Free-living protocol

A subsample of participants from Study 3 (Chapter 6) were fitted with three monitors: an AG GT9X and GA (both on the non-dominant wrist, with AG distal to GA) as well as an activPAL on the right thigh. They were asked to wear the monitors for two days, only removing the wrist-worn monitors for water-based activities. Participants were given log sheets to record when they removed the monitors. After two days the GA and activPALs were collected, while participants continued to wear the AG as part of Study 3.

4.2.4 Accelerometer data processing and reduction

Accelerometer data processing and reduction were completed using manufacturers' software and R-package GGIR, as described in General methods (Chapter 3, section 3.6). GGIR further reduced the data by calculating the average values per 1 s epoch. The first and last 30 s of data from each activity were excluded to remove any potential transitional movements. The central four minutes were manually extracted and utilised for analysis. Data from all the participants (27) completing the sedentary activities were used to compare accelerometer output across brands and placements. All resulting values are expressed in milli (10^{-3}) gravity-based acceleration units (mg), where 1 g = 9.81 m/s^2.

In order to generate raw acceleration sedentary thresholds using receiver operating characteristic (ROC) curve analysis, data from activPAL were used as the criterion standard. The activPAL "Event" files provide exact time in seconds when postural changes occur, classifying events into sedentary, stand and step. Using an Excel formula, these files were expanded to second-by-second data, classifying each second into sit/lie (0), stand (1) or step (2). The activPAL files contain duplicate seconds, where two postures occurred during the same second. Our Excel formula chose the posture that the participant transitioned into as the classification for that particular second. This happened 28 times (i.e., 28 s) during the 28 h and 20 min of data used for the analysis. All 27 participants' data from the sedentary stations were used in this part of the analysis, together with 23 of the participants' playtime data. During one data collection session, cold weather prohibited three participants from going outside to play during break time and on another occasion, one participant's activPAL fell off. The resultant second-by-second activPAL files were synchronised with the 1 s ENMO values from AG and GA. ActivPAL data were coded in two different ways: Sit/Lie (0) versus Stand/Step (1) and Sit/Lie/Stand (0) versus Step (1).

During the free-living period, all valid hours between 7:00 and 21:00 on the second day of data collection were included in the analysis. Hours were deemed invalid when the monitors were removed for any number of minutes during that hour, according to the log sheets. Data files were visually inspected using AG, GA and activPAL software, to verify recorded log sheet wear time (Rowlands et al., 2016c). Thirty-one hours were excluded due to non-wear, while two participants' activPALs fell off resulting in another 18 h being excluded.

4.2.5 Data analysis

Factorial repeated-measures analysis of variance (ANOVA), with Bonferroni corrections were undertaken to determine whether there were differences in output between brands (AG and GA) and placements (dominant- and non-dominant wrists) (interaction effect, brand x placement) for each activity on the circuit. Effect sizes are reported as partial eta-squared (η_p^2), with 0.02, 0.13 and 0.26 defined as small, medium and large respectively (Cohen, 1988). Separate one-way repeated measures ANOVAs were undertaken to compare output from the AG hip and wrist monitors. Where assumptions of sphericity were violated, the conservative Greenhouse–Geisser corrected values of the degrees of freedom were used. Only data from the sedentary stations were used for this part of the analysis.

ROC curve analyses were used to identify raw acceleration sedentary and stationary thresholds, from the whole data collection session (sedentary stations and the playtime data), with the activPAL data used as the criterion reference standard. To maximise both sensitivity and specificity, the Youden index (*J*; Perkins and Schisterman (2006)) was used to identify thresholds. Two ROC curves were generated for each of the five monitors used: the first one was to distinguish between sedentary and non-sedentary behaviours (i.e., sit/lie versus stand/step), while the second one distinguished between stationary and active behaviour (i.e., sit/lie/stand versus step).

In addition, all free-living seconds with a corresponding accelerometer output below the developed thresholds were coded as either sedentary or stationary, while all other seconds were coded as non-sedentary or non-stationary. Agreement between ST according to the thresholds and time spent sitting according to activPAL was examined using paired t-tests and effect sizes calculated as Cohen's *d* (Cohen, 1988) with 0.2, 0.5 and 0.8 defined as small, medium and large. The same process was completed with the stationary time according to the stationary thresholds and time spent sitting plus standing classified using activPAL. Bland–Altman plots compared AG and GA data with that of activPAL. 95% limits of agreement were calculated by mean difference ±1.96 standard deviation of the differences (Bland and Altman, 1999). Free-living data are expressed in minutes or as percentage of total wear time. Furthermore, we also report the following, as recommended by DeShaw et al. (2018): Pearson product correlations, mean percent errors (MPE), mean absolute percent errors (MAPE), and group level equivalence testing, all as described by DeShaw and colleagues (DeShaw et al., 2018).

Statistical analyses were performed using IBM SPSS, version 24 (IBM, Armonk, UK) and Microsoft Excel 2016 (Microsoft, Redmond, WA, USA) with the level of statistical significance set at $p \leq 0.05$.

4.3 Results

4.3.1 Describing the participants

Descriptive data for all participants are shown in Table 4.2. Mean anthropometric measurements of the two samples were similar, with only slightly higher waist circumference and body mass observed in the free-living sample. The predicted mean age at PHV were similar in the two samples, for both girls and boys (girls in calibration sample: 12.0 years; girls in free-living sample: 11.7 years; boys in calibration sample: 13.4 years; boys in free-living sample 13.3 years).

Table 4.2 Descriptive characteristics of the participants [mean (SD)]

Variable	Calibration Study (*n* = 27)	Free-Living Data (*n* = 21)
Age (years)	10.2 (0.3)	10.2 (0.3)
Stature (cm)	141.5 (6.9)	142.8 (7.4)
Sitting height (cm)	70.9 (3.9)	71.3 (3.3)
Waist circumference (cm)	66.7 (10.9)	70.3 (9.8)
Body mass (kg)	37.3 (11.4)	40.8 (10.6)
BMI (kg/m^2)	18.3 (3.9)	19.8 (4)

4.3.2 Comparison of activities, accelerometer brands and placements

A factorial repeated measures ANOVA showed a significant main effect of activity on accelerometer output ($F_{1.47,\ 9548} = 18{,}279$; $p < 0.0001$; $\eta_p^2 = 0.74$). Pairwise comparisons revealed significant mean differences between most activities (all $p < 0.0001$, except standing with phone was higher than homework p = 0.001, and TV viewing was significantly higher than standing with phone $p = 0.003$). No significant difference was found between resting and sitting with tablet ($p = 0.655$). Table 4.3 shows mean accelerometer output from both wrists and both brands, for each activity. A significant main effect of brand was found ($F_{1,\ 6479} = 36$; p < 0.0001; $\eta_p^2 = 0.006$), with output from GA slightly higher than AG (mean difference = 1.44, standard error (SE) = 0.24, 95% confidence interval (CI) [0.97–1.91]). A non-significant main effect of placement (dominant and non-dominant wrists) ($p = 0.259$) was observed. However, individual two-factor repeated measures ANOVAs for each activity showed significant main effects of placements (dominant and non-dominant wrists) for all activities except for TV viewing ($p = 0.321$). When analysing AG data separately (hip and wrists), a significant main effect of placement was found ($F_{1.97,\ 12761} = 2343$; $p < 0.0001$; $\eta_p^2 = 0.266$).

A significant three-way interaction effect (activity × brand × placement) was observed ($F_{1.77,\ 11489} = 16.8$; $p < 0.0001$; $\eta_p^2 = 0.003$). Separate analyses per activity showed significant interactions between brand and placement (dominant and non-dominant wrists) for all the activities except TV viewing ($p = 0.145$) and walking ($p = 0.293$): homework ($F_{1,\ 6479} = 119$; $p < 0.0001$), LEGO® ($F_{1,\ 6479} = 122$; $p < 0.0001$), resting ($F_{1,\ 6479} = 50.2$; $p < 0.0001$), sitting with tablet ($F_{1,\ 6479} = 10.8$; $p < 0.0001$), standing with phone ($F_{1,\ 6479} = 17.1$; $p < 0.0001$).

Table 4.3 Mean accelerometer output from both brands and wrists, for all activities, from highest to lowest

Activity	Mean Acceleration (m*g*)	95% Confidence Interval Lower Bound	Upper Bound
Walking	190.7	188.4	193.0
LEGO®	31.0	30.6	31.4
Seated, tablet	20.5	20.0	21.0
Resting	19.6	19.0	20.2
TV viewing	15.0	14.5	15.5
Standing, phone	13.9	13.5	14.1
Homework	13.0	12.7	13.3

Output from the AG hip monitors were significantly lower than the AG dominant ($p < 0.0001$) and non-dominant wrist monitors ($p < 0.0001$). Overall there was no significant difference found between the two wrist placements for both devices ($p = 0.259$), but analysing the activities individually showed significantly higher output from the dominant wrist during homework, LEGO®, resting, sitting with tablet and standing with phone (all with $p < 0.0001$) compared to non-dominant wrist, while no significant difference between wrists was observed while TV viewing ($p = 0.32$) and a significantly higher output from non-dominant wrist was observed during walking ($p < 0.0001$).

During four activities, the GA wrist monitors produced a significantly higher output than the AG wrist monitors: homework ($p < 0.0001$), walking ($p < 0.006$), LEGO® ($p < 0.0001$), and sitting with tablet ($p = 0.032$). With the exception of homework, these were also the activities with the highest overall mean accelerometer output. The opposite was observed for the other three activities, with AG wrist outputs significantly higher than GA for: resting ($p < 0.0001$), standing with phone ($p < 0.0001$) and TV viewing ($p = 0.003$). Table 4.4 shows the mean accelerometer output from AG and GA monitors for all placements across the seven stations, with symbols indicating significant differences between placements and brands from each activity.

4.3.3 Threshold Generation

Table 4.5 shows the results from the ROC curve analysis, with the developed sedentary and stationary thresholds. Thresholds for the hip monitors are lower than for wrist-worn monitors. Classification accuracy was significantly better than chance for sedentary and stationary ROC curves. Classification accuracy was however lower for sedentary behaviour (area under the curve (AUC) 0.746–0.797), in comparison to stationary behaviour (AUC 0.888–0.944) (see Figure 4.1, two ROC curves from AG non-dominant wrist data, as an example). Sensitivity was high for all the thresholds identified (>80%), but specificity was lower for the sedentary thresholds (51%–60%). Whereas, specificity for the stationary thresholds was higher ranging from 85%–89%.

Similar acceleration thresholds were identified for sedentary and stationary behaviours, with the exception of the non-dominant wrist placements (both AG and GA), which found slightly higher thresholds for classifying stationary behaviour.

Table 4.4 Accelerometer output [mean (SD)] from ActiGraph (AG) and GENEActiv (GA) monitors, expressed in m*g*, across all stations (*n* = 27).

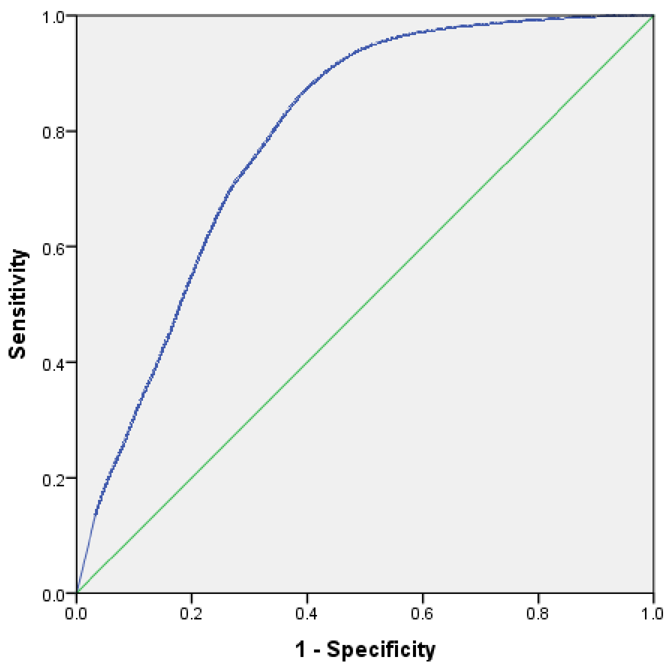
Device	Resting	TV viewing	Seated, tablet	Standing, phone	Seated, LEGO®	Seated, Homework	Walking
AG hip	8.9 (12.4) *	5.5 (7.7) *	8.4 (8.6) *	3.9 (8.1) *	6.5 (8.0) *	5.3 (8.5) *	148.2 (51.5) *
AG Dom	23.5 (34.1) †,#	15.2 (27.7)	21.5 (28.7) †	16.7 (19.2) †,#	32.8 (25.7) †,#	13.5 (19.8) †,#	178.0 (139.3) †,#
GA Dom	18.0 (38.6)	14.5 (33.2)	21.4 (32.6) †	14.8 (18.9) †	36.6 (29.9) †	19.0 (23.4) †	183.1 (115.4) †
AG Ndom	18.7 (36.1)	15.8 (27.8) #	18.6 (29.3) #	12.0 (23.5)	21.8 (27.6) #	9.3 (19.1) #	199.3 (131.0)
GA Ndom	17.9 (36.4)	14.4 (27.8)	20.4 (30.8)	11.9 (21.8)	32.6 (31.6)	10.2 (20.5)	202.1 (129.3)

* significantly different from wrists ($p < 0.0001$), † = significantly different from non-dominant wrists ($p < 0.05$), # = AG significantly different from GA ($p < 0.05$).

Table 4.5 Sensitivity, specificity, area under the curve (AUC) and 95% confidence intervals (CI), with proposed thresholds for ActiGraph (AG) hip, dominant- (Dom) and non-dominant (Ndom) wrists as well as GENEActiv (GA) dominant and non-dominant wrists in children.

	Sedentary Behaviour					Stationary Behaviour				
Device	Sensitivity (TPR *)	Specificity (TNR †)	AUC	95% CI	Threshold (m*g*)	Sensitivity (TPR)	Specificity (TNR)	AUC	95% CI	Threshold (m*g*)
AG hip	97%	51%	0.746	0.743–0.75	**32.6**	94%	86%	0.944	0.942–0.946	**32.6**
AG Dom	89%	55%	0.759	0.756–0.762	**55.6**	86%	87%	0.926	0.924–0.928	**55.2**
AG Ndom	87%	60%	0.797	0.788–0.793	**48.1**	87%	89%	0.940	0.939–0.942	**57.5**
GA Dom	84%	57%	0.752	0.749–0.755	**56.5**	82%	85%	0.888	0.886–0.891	**59.1**
GA Ndom	87%	57%	0.77	0.768–0.773	**51.6**	86%	85%	0.918	0.916–0.920	**60.7**

* True Positive Rate † True Negative Rate.



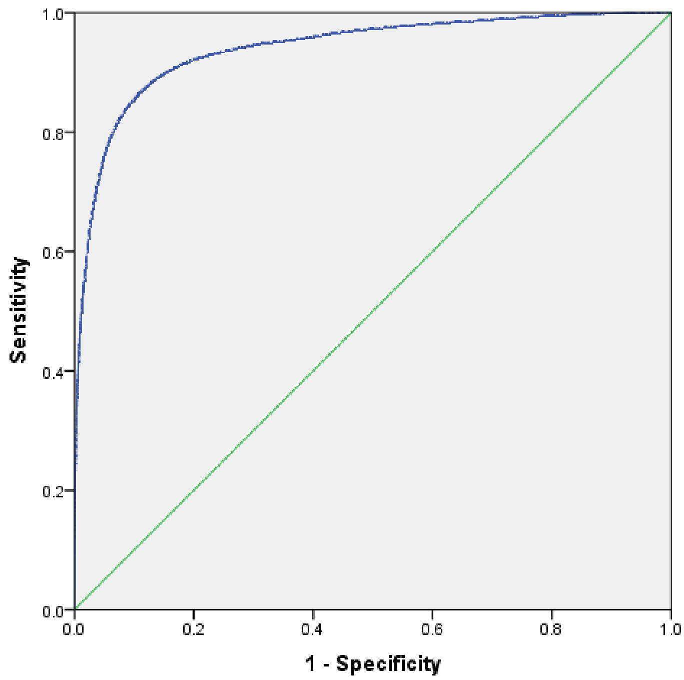


Figure 4.1: ROC curves of ActiGraph non-dominant wrist data, showing classification accuracy of sedentary behaviour (top figure, Area under the curve = 0.79) and stationary behaviour (bottom figure, Area under the curve = 0.94).

4.3.4 Validation of thresholds during free-living time

During the free-living period, mean wear time was 700 ± 176.9 min (11.7 hrs). Participants spent on average 67% (466.3 ± 131.9 min) of their time seated according to activPAL. The corresponding estimates of ST according to the developed sedentary thresholds were both significantly higher (AG: 71%, 499.5 ± 143.1 min, $p = 0.003$, $d = 0.25$ and GA: 73%, 509.8 ± 145 min, $p < 0.001$, $d = 0.33$). Conversely, estimates of stationary time according to the developed stationary thresholds were both significantly lower (AG: 75%, 522.1.1 ± 147.6 min; $p < 0.001$; $d = 0.46$ and GA: 76%, 529.6 ± 148.5 min, $p < 0.001$, $d = 0.4$) compared to time spent sitting/lying plus standing according to activPAL (85%, 594.6 ± 161.2 min). Table 4.6 summarises the various indicators of measurement agreement between the two brands against the reference, activPAL. On average, AG overestimated ST by 4% compared to activPAL, with a computed MPE of −7.3% and MAPE of 9.5%. Similarly, GA overestimated ST by 6%, with a computed MPE of −9.5% and MAPE of 10.6%. AG on average underestimated stationary time by 10% compared with activPAL, with the same computed MPE and MAPE values (both 12.2%). GA underestimated stationary time by 9%, with both MPE and MAPE values of 10.9%. Correlations with activPAL were high for ST (both brands: $r = 0.95$, $p < 0.001$) and stationary time estimates (both brands $r = 0.98$, $p < 0.001$). Figures 4.2 and 4.3 show Bland–Altman plots assessing the agreement between ST from activPAL and ST from AG (4.2, top figure) and GA (4.2, bottom figure) and agreement between stationary time from activPAL and stationary time from AG (4.3, top figure) and GA (4.3 bottom figure). The sedentary thresholds had smaller mean biases (AG = +33 min; GA = +44 min) than the stationary thresholds (AG = −72 min; GA = −65 min). Both sedentary thresholds had wider limits of agreement (AG: from −54 to +120 min, GA: from −44 to +132) than the stationary thresholds (AG: from −141 to −4 min, GA: from −124 to −6 min).

Table 4.6 Sedentary and stationary time estimates from AG and GA free-living data compared with activPAL.

Criterion	Comparison	Mean (SD) minutes	MPE (SD)	MAPE (SD)	Limits of Agreement (Lower to Upper)	95% CI of mean biases (Lower to Upper)	Correlation	*p* Value	Equivalency Analysis (minutes)
Sedentary time									
activPAL (sit/lie)		466.3 (131.9)							Zone of Equivalence: 419.6–512.9
	AG (48 mg)	499.5 (143.1)	−7.3% (10.5%)	9.5% (8.5%)	−54 to 120	13 to 53	0.95	0.003	90% CI 483.6–515.3
	GA (52 mg)	509.8 (145.0)	−9.5% (10.1%)	10.6% (8.8%)	−44 to 132	23 to 64	0.95	<0.001	90% CI 493.8–525.9
Stationary time									
activPAL (sit/lie/stand)		594.6 (161.2)							Zone of equivalence: 535.1–654
	AG (58 mg)	522.1 (147.6)	12.2% (5.6%)	12.2% (5.6%)	−141 to −4	−88 to −57	0.98	<0.001	90% CI 509.6–534.5
	GA (61 mg)	529.6 (148.5)	10.9% (4.9%)	10.9% (4.9%)	−124 to −6	−79 to −51	0.98	<0.001	90% CI 518.7–540.4

MPE = mean percentage error; MAPE = mean absolute percentage error; CI = confidence interval.

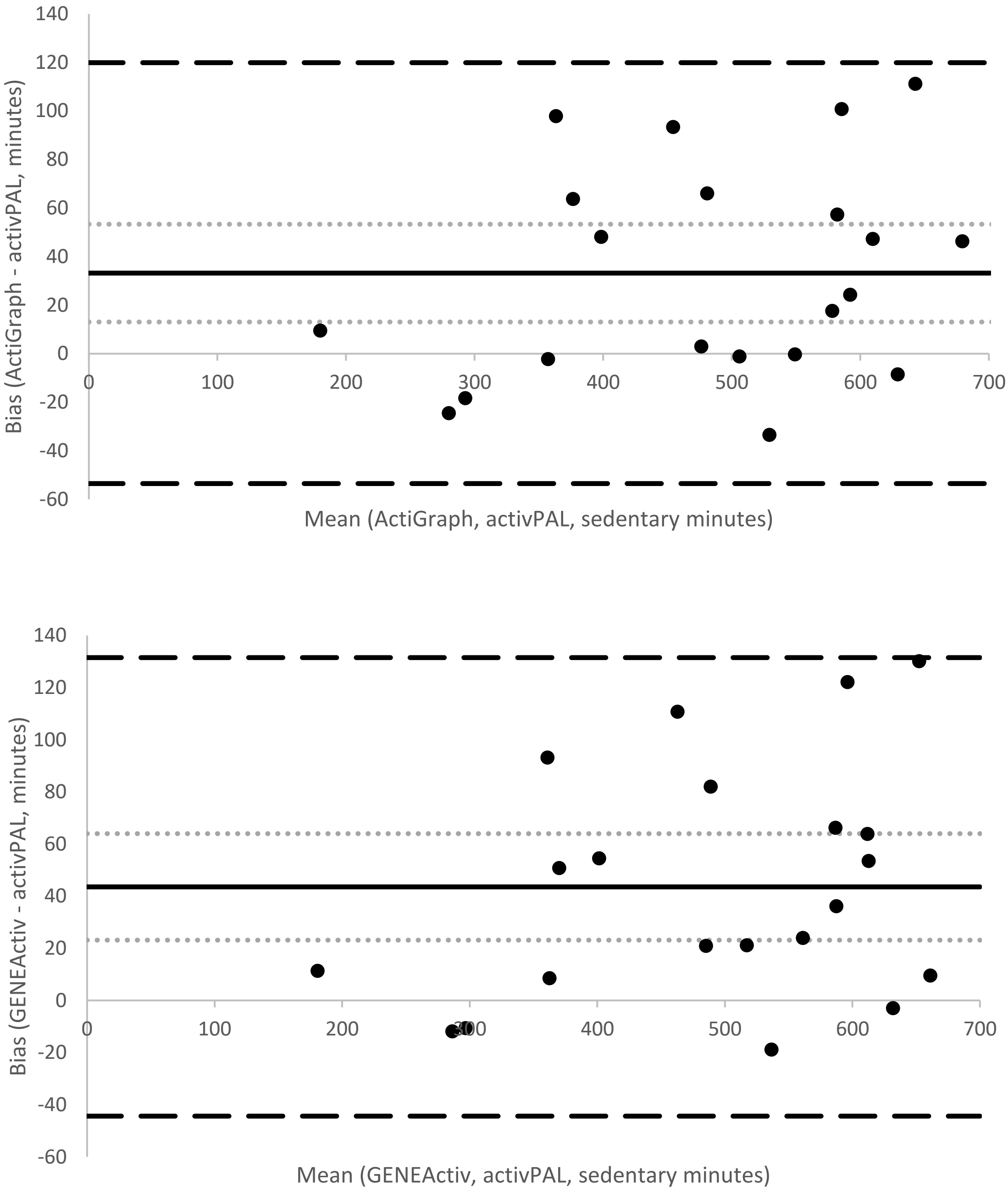


Figure 4.2 Mean bias (solid line), 95% CI of the mean bias (light dotted lines) and 95% limits of agreement (large dashed lines) for the sedentary free-living time estimated by the developed thresholds for Actigraph non-dominant wrist (top figure) and GENEActiv non-dominant wrist (bottom figure) relative to activPAL.

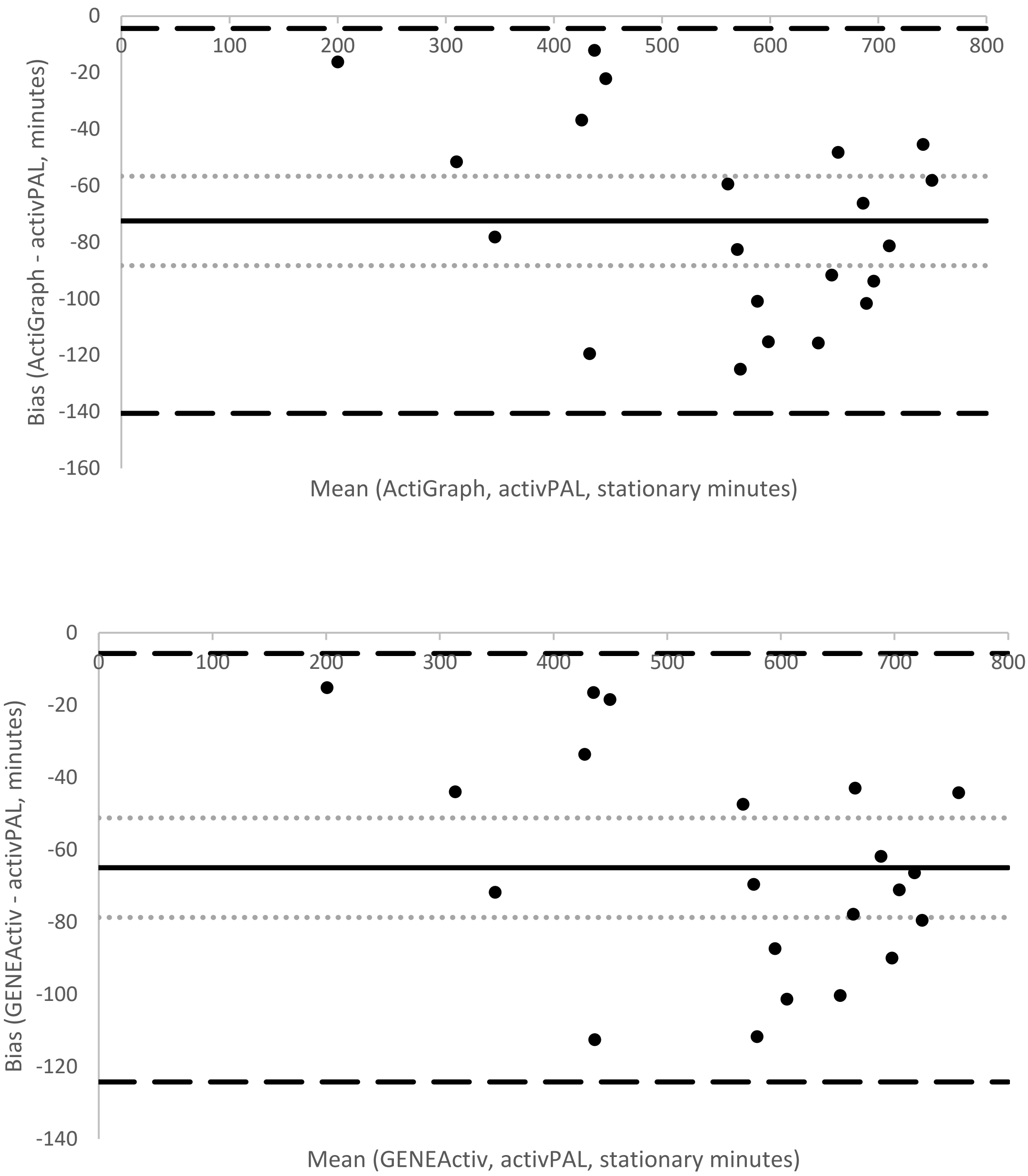


Figure 4.3 Mean bias (solid line), 95% CI of the mean bias (light dotted lines) and 95% limits of agreement (large dashed lines) for the stationary free-living time estimated by the developed thresholds for ActiGraph non-dominant wrist (top figure) and GENEActiv non-dominant wrist (bottom figure) relative to activPAL.

Figure 4.4 shows the equivalence zones for sedentary (top figure) and stationary (bottom figure) time estimates from AG and GA compared to activPAL. While none of the estimates were found to be statistically equivalent on average at the group level to activPAL when using 10% of the activPAL mean as the zone of equivalence, the AG sedentary threshold of 48 mg was closest to achieving group-level equivalence. The figures clearly show that the sedentary thresholds slightly overestimated, while the stationary thresholds underestimated time spent sedentary or stationary in comparison with activPAL. Extending the zone of equivalency to 15% of the activPAL mean resulted in both the GA and AG stationary and sedentary thresholds achieving equivalency with activPAL (see Figure 4.4).

A significant difference was found between AG and GA sedentary time (mean difference = −10.4 min, SE mean = 3.4, $p = 0.006$), however this difference yielded a small effect size of $d = 0.07$. Similarly, a significant difference was found between AG and GA stationary time (mean difference = −7 min, SE mean = 2.6, $p = 0.01$, $d = 0.05$). Figure 4.5 shows Bland–Altman plots assessing the agreement between sedentary and stationary time from AG and GA. Both had small mean biases (sedentary time = +10.4 min; stationary time = +7.5 min), and narrow limits of agreement (sedentary time −19.8 min to +40.5 min, stationary time from −16 min to +30.9 min).

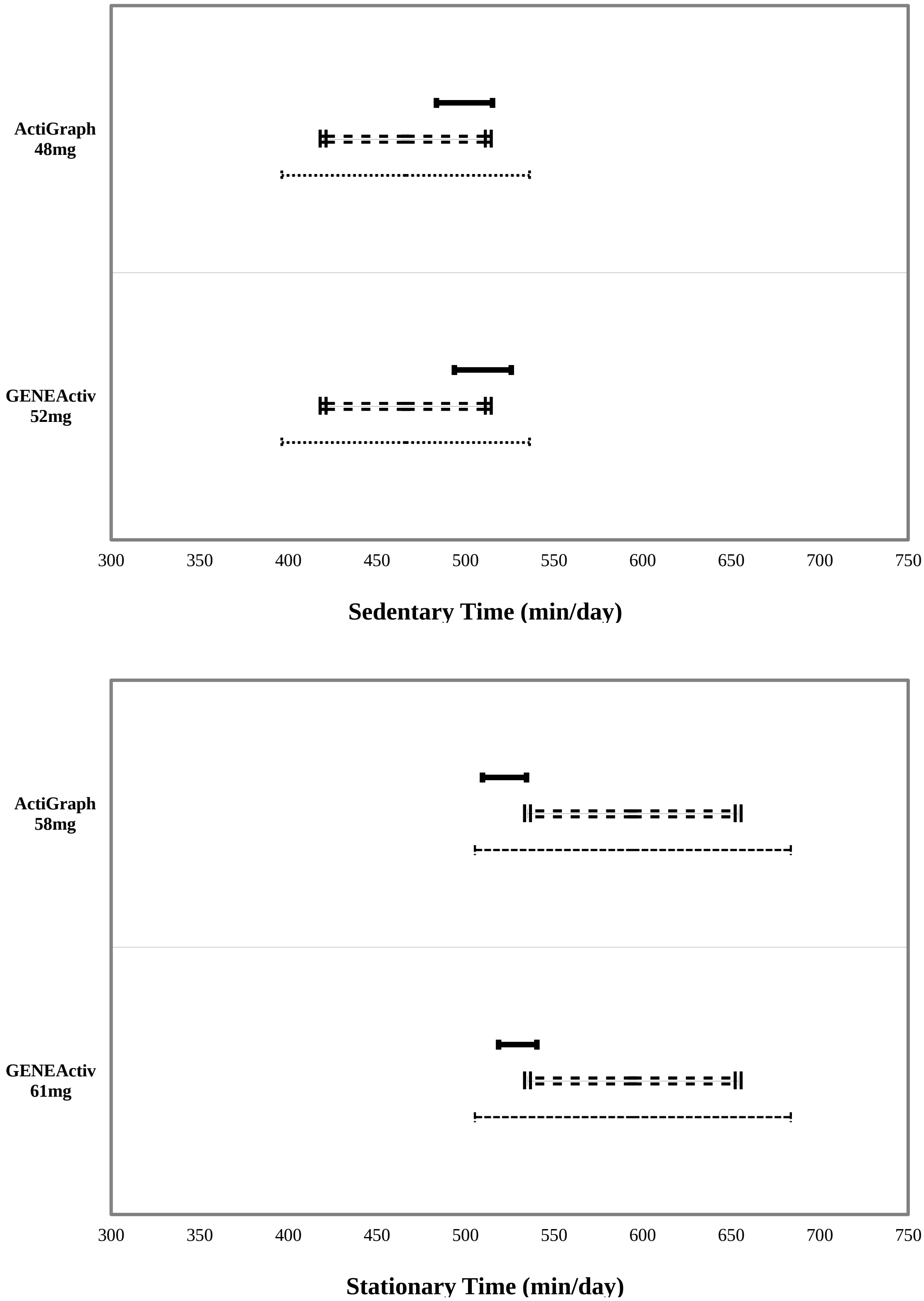
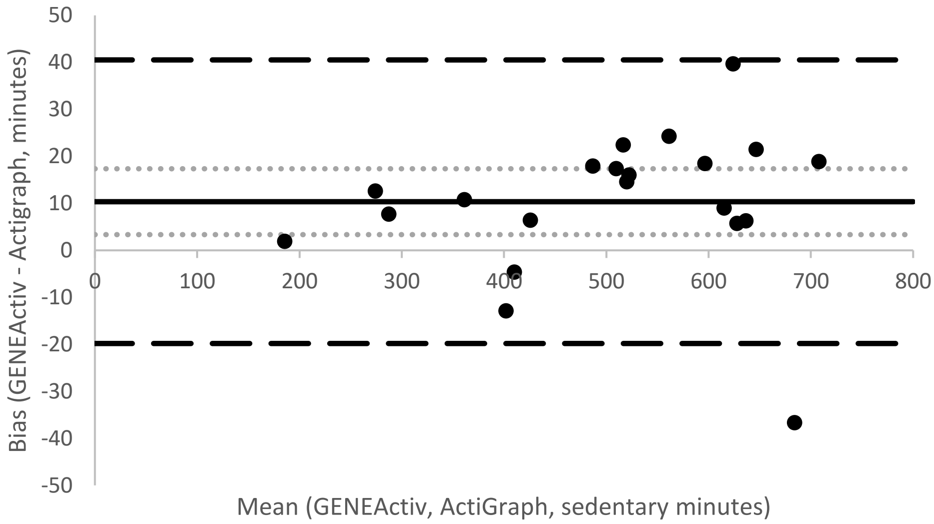


Figure 4.4 activPAL sedentary (top figure) and stationary (bottom figure) time zones of equivalence (10% = double dotted lines, 15% = single dotted lines) and 90% confidence intervals for the ActiGraph and GENEActiv sedentary and stationary time estimates classified using the developed thresholds.



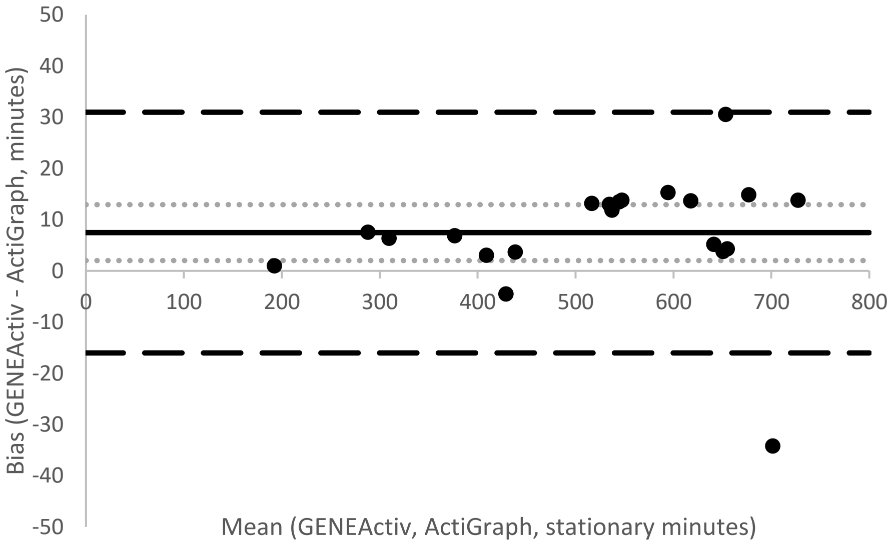


Figure 4.5 Bland–Altman plots comparing sedentary (top figure) and stationary (bottom figure) time estimates from the developed thresholds between GENEActiv and ActiGraph. The figure displays mean bias (solid line), 95% CI of the mean bias (light dotted lines), and 95% limits of agreement (large dashed lines).

4.4 Discussion

The first aim of this study was to compare the raw accelerometer output of AG and GA accelerometers across three different placements. The significantly lower output observed from the AG hip monitors (compared with wrists) is consistent with previous findings (Fairclough et al., 2016; Hildebrand et al., 2016; Noonan et al., 2016c). These results suggest that SB studies should not compare data collected using hip monitors to ones using wrist monitors unless effective harmonisation approaches are used that correct for the differences in observed accelerations (e.g. Boddy et al., 2019).

Inconsistent differences between monitors and placements were observed across the range of sedentary and stationary activities. The differences by activity could be attributed to the nature of the SBs themselves. While the unique nature of children's PA patterns have been well established (Welk, Corbin and Dale, 2000), little is known about differences in their SBs. For example, the homework and standing with phone stations overall had the lowest average accelerometer output of all the stations, even lower than TV viewing and resting. Even though statistically significant, many of these differences were small, as seen in Tables 4.3 and 4.4. With the exception of walking and LEGO®, the mean differences in output between activities ranged from 0.88 mg to 7.48 mg, differences that are unlikely to be meaningful. A possible explanation for the inconsistencies observed between monitors might be internal differences between devices. Again, the difference observed between brands, although statistically significant, yielded a small effect size, which is unlikely to be meaningful. The dominant wrist monitors produced a higher output for most of the activities. Previous studies have used either the non-dominant wrist (Fairclough et al., 2016; Rowlands et al., 2016a) or the dominant wrist (John et al., 2013; Crouter, Flynn and Bassett, 2015). Two studies that compared wrist placements (Esliger et al., 2011; Phillips, Parfitt and Rowlands, 2013) found no significant differences between these two sites; however, these studies did not differentiate between dominant and non-dominant wrists, but rather compared the right side with the left. Buchan, Boddy and McLellan (2019) compared activity outcomes from AG GT3X on dominant- versus non-dominant wrist placements, and found that the two placements did not yield statistically equivalent (10% zone of equivalence) ST and LPA outcomes (according to ENMO cut-points) in free-living adults. Crouter, Flynn and Bassett (2015) argues for the use of the dominant wrist in an effort to capture more activities requiring the use of the dominant hand, while Chandler et al. (2018) recommends using the non-dominant wrist to ensure that sedentary activities like writing or colouring are not misclassified as PA.

The second aim of this study was to develop raw acceleration thresholds for SBs in children. The lower classification accuracy (AUC) for differentiating between sedentary and non-sedentary behaviour may be partially attributed to the misclassification of some activities by activPAL. Comparing the direct observation notes with the activPAL data showed that activPAL misclassified sitting as standing on a number of occasions for different participants. For example: for two participants activPAL misclassified the entire duration of the seated homework station (5 min) as standing. Similar inconsistencies were found throughout the data which amounted to a total of 30 min (out of 1700 min in total, or equal to 1.7%) of data. This may have had an impact on the accuracy of the thresholds generated using activPAL and the free-living validation. A possible explanation for this may lie in the nature of children's SBs (not sitting completely still for example). Participants might have been sitting on the edges of their seats, with their legs hanging down and thighs outside of the threshold angle to be classified as sitting by activPAL. Children were instructed to sit, however, researchers did not ask participants to sit with their legs at a specific angle to reflect the 'typical' behaviour of each child. The misclassifications observed suggest that the activPAL may underestimate sitting and overestimate standing, which is consistent with findings from another study (Davies et al., 2012). Validation studies have shown almost perfect correlation between activPAL and direct observation (r = 0.99) in both adults (Lyden et al., 2012) and children (Aminian and Hinckson, 2012). While these studies used the older, uni-axial activPAL, its agreement with the tri-axial activPAL3 for characterising posture has proved to be high (>95%) (Sellers et al., 2016). Other observations made by the researchers include the participants' inability to lie still during the resting station. Participants were instructed to lie down and rest, as still as possible. This in practice seemed very difficult for the participants, which explains why the resting station did not result in the lowest accelerometer output, as might have been expected. Rather, it ranks fourth in total accelerometer output, with TV viewing, standing with phone and the homework station resulting in lower total accelerometer outputs.

The stationary activity 'standing with phone', produced the second lowest output from wrist monitors and the lowest output from hip monitors, highlighting the fact that children stand exceptionally still while playing with a mobile phone. Adding "stand" to the second ROC curve analysis (stationary behaviour) resulted in higher classification accuracy (the lowest being the GA dominant wrist with an AUC = 0.888 and highest the AG hip with AUC = 0.944) than when standing was excluded. Using stationary activity also removed the issues associated with the misclassification of activities by the activPAL. Despite this, the resultant thresholds for stationary behaviour are similar to those for SB, except for a slight difference between non-dominant wrists. Using the dominant wrist thresholds in future studies would thus capture both stationary and SBs.

In comparison to those of Hildebrand et al. (2016), our threshold for AG hip monitors is lower (32.6 m*g* versus 63.3 m*g*), while our AG non-dominant wrist threshold is higher (48.1 m*g* versus 35.6 m*g*). Our GA non-dominant wrist threshold is slightly lower than that of Hildebrand et al. (51.6 m*g* versus 56.3 m*g*) who did not include the dominant wrist in their protocol. Sensitivity and specificity were higher in the Hildebrand et al. results, possibly because of protocol differences: Hildebrand used two sedentary activities in a controlled laboratory environment and four light-to-vigorous physical activities. Hildebrand also concluded that posture misclassification from activPAL might have attributed to the lower specificity observed. Another noticeable difference between our results and those from Hildebrand is that our specificity increased greatly when we included the standing activity (e.g., from 57% to 85% for the GA non-dominant wrist monitors), while Hildebrand's increased when they excluded the standing activity from their analysis. This observation is likely due to protocol differences. For example, during a standing activity in the Hildebrand protocol, children were allowed to draw on a whiteboard, which probably resulted in more movement than our standing with a phone station.

Our GA non-dominant wrist threshold (51.6 m*g*) is similar to the recently published 51 m*g* by Boddy et al. (2018). Our sensitivity was slightly higher than that of Boddy et al. (2018) (87% versus 81%), with both studies' specificity at 57%. There is a 3.5 m*g* and 3.2 m*g* difference in our resultant sedentary and stationary thresholds estimated with AG and GA for non-dominant wrist, respectively. As previously stated, these small differences might be the result of internal differences between devices, and unlikely to be meaningful in practice. Future researchers might decide to use 50 m*g* as sedentary threshold and 60 m*g* as stationary threshold for both brands, facilitating comparisons between studies.

For two participants, there were periods classified as sitting by activPAL during break time. Observational data showed that the participants were not sitting, but rather hunching down during play (for example crouching behind an object during hide and seek). While the posture classification from activPAL was correct, the behaviour was not sedentary, which again highlights the differing nature of children's SBs in comparison to adults and the value of observational data. Similar observations were made during an activPAL validation in preschool children (Davies et al., 2012) whereby the postures lie, sit, stand and walk were too limited for the range of positions children assume during playtime. Cumulatively these findings question the suitability of using activPAL to classify what appears to be a wide range of SBs performed by children.

During the free-living period, results from the paired t-tests as well as the various indicators of measurement agreement suggested that the sedentary thresholds performed better than the stationary thresholds compared with data from activPAL. The sedentary cut points for both AG and GA slightly overestimated time spent sedentary compared with time spent sitting/lying according to activPAL. While these were significant differences, the effect sizes were relatively small and equivalence testing showed that the 48 m*g* AG cut point came close to achieving equivalency within 10% of the activPAL mean, on average at the group level. Conversely, stationary cut points for both AG and GA underestimated time spent sitting/lying plus standing according to activPAL. For both brands, the computed MPE and MAPE values for the stationary thresholds were the same, confirming that all the error was in one direction (i.e., an underestimation of stationary time).

The main reason for the differences observed between cut points and activPAL data is that we are essentially comparing a lack of movement (or very little movement) with posture classifications. When using cut points to analyse SB data, researchers should acknowledge that there are certain circumstances that can result in misclassification. For example, where a lack of movement at the wrist will be classified as sedentary using cut points, the participant might in fact be standing. Conversely, the stationary thresholds' underestimation of stationary time is likely due to children moving their arms while standing. This behaviour is called "active standing" (defined as waking activity characterised by energy expenditure above 2.0 METs, while standing without ambulation (Tremblay et al., 2017)). When using cut points to analyse the data, it is unlikely that wrist-worn accelerometers would be able to differentiate between active standing and light-intensity physical activity with ambulation, for example slow walking, meaning this behaviour is incorrectly classified. Achieving an accurate estimate of stationary behaviours appears to be challenging using wrist-mounted accelerometers in the absence of postural information, resulting in an overestimation of ST. Whilst the recently published consensus definitions of sedentary and stationary behaviours are based on sound theory (Tremblay et al., 2017), from a health perspective, it is better to overestimate ST than to underestimate sedentary or stationary behaviours, as misclassified children can still participate in interventions aiming to decrease sedentary or stationary time without causing any harm. Conversely, underestimating ST might result in children not being identified for intervention and ultimately exposed to increased health risk. Equivalency was achieved by extending the zone of equivalence to 15% of the activPAL mean. However, where more accurate measures of sedentary and stationary time from wrist-worn accelerometers are needed, using postural approaches such as the Sedentary Sphere (Rowlands et al., 2014) method in children might be a better option, although validation studies are required to examine this further.

This study has several strengths. The protocol included seven different activities, representing a wide range of 'typical behaviours' in children, as well as playtime data. It took place in a school gymnasium and outside on the playground, spaces that the participants were familiar and comfortable with. This increased the ecological validity of the protocol involved. The participants wore six different monitors each, and raw data processing as opposed to proprietary counts allowed for various direct comparisons between brands and placements. There are also some limitations: we used a convenient sample and all the participants came from the same school, which might not be representative of the wider population. The homogeneous sample of 9- to 10-year-old children should not be considered representative of all age groups, and researchers should look to age-specific studies for thresholds developed for younger children or older adults (e.g. Sanders et al., 2019). The activities were not performed in the same order for each participant, however, no formal randomisation techniques were used. AG and GA monitors were placed next to each other on the wrist, in no specific or consistent order (Rowlands et al., 2018b). Placing one brand consistently distal to the other might have resulted in increased acceleration from that brand, however no formal randomisation techniques were used. Whilst activities were designed to reflect children's typical SBs, METs could not be measured and as a result we cannot assume that energy expenditures during the protocol were at all times ≤ 1.5 METs. The protocol in the school gymnasium highlighted the fact that activPAL sometimes misclassifies children's postures, and we have to assume that the same might have happened during the free-living period. However, except for direct observation, there is no other tool that can be used as a criterion measure. Direct observation was unfeasible for this study, as the playground during break time was very busy and not all movements and postures were visible to the researchers at all times.

4.5 Conclusions

This study has identified raw acceleration sedentary and stationary thresholds for the AG hip, dominant and non-dominant wrists as well as the GA dominant and non-dominant wrists for children. The stationary thresholds underestimated stationary time when applied to free-living data in relation to activPAL. The sedentary thresholds were not comparable; however, effect sizes were small and the AG cut point came close to achieving equivalence with activPAL on average at the group level. Comparisons between accelerometer brands and placements in the calibration study produced inconsistent results; however, the free-living data confirmed that these differences are small. Future studies focusing on the nature of children's SBs may provide insight into the reasons for the differences observed.

Thesis study map

Study	Aims and key findings
Study 1: Establishing raw acceleration thresholds to classify sedentary and stationary behaviours in children	**Aims:** 1. To compare the raw accelerometer output of ActiGraph (AG) and GENEActiv (GA) accelerometers across different placements, 2. To identify raw acceleration signal thresholds for different sedentary behaviours in children, from both the hip and wrist, using AG and GA, 3. To validate the thresholds during free-living activities. **Key findings:** • Hip worn AG monitors resulted in significantly lower acceleration output compared to wrist worn monitors, and are not comparable. • Statistically significant differences between accelerometer outputs of sedentary activities were observed, however these differences are unlikely to be meaningful in practice. • Inconsistent differences between GA and AG monitors were observed during calibration, however free-living data confirmed that the differences were small and unlikely to be meaningful in practice. • Sedentary and stationary thresholds were developed for AG hip, AG and GA non-dominant and dominant wrist placements. • The sedentary thresholds slightly overestimated free-living sedentary time compared with activPAL. The stationary thresholds underestimated stationary time according to activPAL.
Study 2: Validating the Sedentary Sphere method in children.	**Aims:** 1. To validate the Sedentary Sphere method of classifying posture, in child populations using GENEActiv and ActiGraph GT9X wrist-worn accelerometers

Study 3: Exploring a novel mixed-methods approach to assess children's sedentary behaviours.
Study 4: Parental perceptions of the factors influencing children's sedentary behaviours.

CHAPTER 5

STUDY 2

VALIDATING THE SEDENTARY SPHERE METHOD IN CHILDREN

The main outcomes of this study have been published in *Journal of Sport Sciences*: Hurter, L., Rowlands, A.V., Fairclough, S.J., Gibbon, K.C., Knowles, Z.R., Porcellato, L.A., Cooper-Ryan, A.M. and Boddy, L.M. (2019) Validating the Sedentary Sphere method in children: Does wrist or accelerometer brand matter? *Journal of Sports Sciences*, 37 (16), 1910-1918.

5.1 Introduction

Chapter 4 identified raw acceleration sedentary thresholds for both GA and AG accelerometers, which can be used to quantify ST, as characterised by an absence of or low levels of dynamic acceleration. This approach, however, does not take into account the postural element of SB. Posture classification is vital in the measurement of SB and is central to its definition (Tremblay et al., 2017). The ability to accurately classify SB and PA using one accelerometer would be advantageous to the discipline, as it would remove the requirement for additional devices that classify posture such as the activPAL. In turn, this would reduce participant burden, researcher processing time, and financial costs involved with running a study. Researchers have been calling for such a solution, i.e. a feasible method that would allow the use of one accelerometer able to classify posture as well as providing raw acceleration data (Hildebrand et al., 2016; Boddy et al., 2018). In children, such a device should preferably be a wrist-worn monitor, as compliance is highest with wrist-worn devices (Fairclough et al., 2016) and children view it as more socially desirable than other devices or placements (McCann et al., 2016). Additionally, compliance with activPAL is low in children (Sherry et al., 2018) and adolescents (Shi et al., 2019), with the latter reporting the seven days of wear time to be too long and preferring not to wear it again (Shi et al., 2019).

Rowlands and colleagues first introduced the concept of the Sedentary Sphere in 2014 as a new method of analysing, identifying and visually presenting data from the wrist-worn GA accelerometer. The Sedentary Sphere uses arm elevation to classify the most likely posture in adult populations (Rowlands et al., 2014), thus providing a pragmatic solution to the lack of postural classification using the magnitude of acceleration intensity alone. During periods of inactivity, gravity provides the primary signal to the accelerometer and the Sedentary Sphere uses this gravitational component of the acceleration signal to determine the orientation of the monitor and therefore, the position of the wrist (Rowlands et al., 2014). In a subsequent study, Rowlands and colleagues further validated this approach for posture classification using data from the widely used AG GT3X accelerometer, worn on the wrist (Rowlands et al., 2016c). The Sedentary Sphere represents a promising and feasible approach to measuring ST that can be applied to the many large observational datasets using wrist-worn GA or AG accelerometers to assess children's physical behaviours (e.g. the Pelotas Birth Cohort (da Silva et al., 2014), the Melbourne Child Health Checkpoint (Wake M et al., 2014), the Cork Children's Lifestyle Study (Li et al., 2017) and the National Health and Nutrition Examination Survey 2011-2014 (Troiano et al., 2014)). To date, application of the Sedentary Sphere concept has not been validated in children; therefore, this study aims to investigate whether the Sedentary Sphere method of classifying posture using GA and AG GT9X wrist-worn accelerometers, can be used in its current state in child populations.

5.2 Methods

5.2.1 Participants

This is a secondary data analysis, using data generated in Study 1 (the methods are described in Chapter 4, section 4.2). As with Study 1, the first part of the analysis was taken from the calibration protocol conducted in a school gymnasium and on the school playground (n = 27, 9-10 years old, 17 girls), while the second part came from a subsequent study (Study 3, Chapter 6) to provide added free-living data (n = 21, 9-10-year-olds, 13 girls).

5.2.2 Anthropometrics

Anthropometric measurements for both samples were taken as described in General methods (Chapter 3, Section 3.4).

5.2.3 Sedentary behaviour

5.2.3.1 Protocol for sedentary stations and free-play during break time

While each participant wore six accelerometers (as described in Chapter 4, section 4.2.3.1), data from five were used in the analysis for the current study. These were the AG GT9X and GA monitor on each of the dominant and non-dominant wrists (using the manufacturers' straps) and the activPAL monitor (attached with activPAL stickies) worn on the right anterior thigh. AG and GA monitors were placed next to each other on the wrist, but in no consistent or specific order. All monitors were worn throughout the testing protocol, as described in Chapter 4, section 4.2.3.1. The first and last 30 seconds of data from each sedentary station as well as from the 10 minutes of free-play were excluded from the analysis, to remove any data from potential transitional movements. Direct observation was used as the criterion for posture allocation for the seven sedentary and light activities (see Table 5.1 for the posture allocations of each station), while the activPAL monitor was used as the criterion reference for posture allocation during free-play.

5.2.3.2 Protocol for free-living data

In order to add free-living data to the analysis, an independent sample of 21 children wore three monitors for two consecutive days. These children were part of the upcoming Study 3, in which they were asked to wear an AG for 7 days. During the first two days they also wore a GA (proximal to AG) and an activPAL attached to the thigh. As data collection started at 10:00 on the first day, data from the second day (i.e. the first full day's data) was used in the analysis. Participants were requested to wear the thigh devices continually and only remove the wrist-worn devices for water-based activities. The activPAL monitors were waterproofed with small, flexible sleeves and attached with 10-15 cm Tegaderm adhesive. Participants were supplied with log sheets to record times when they removed the monitors.

Table 5.1 Activities undertaken in the school gymnasium.

Posture		Activity
*Sedentary	Resting	Lying on a soft gym mat, in a supine position, asked to avoid bodily movements.
	TV	Sitting comfortably on a couch, watching TV.
	Tablet	Sitting comfortably on a couch, playing the Bike Race game on an iPad.
	Lego	Sitting at a table, playing with Lego.
	Homework	Sitting at a table, copying a piece of writing (mimicking homework).
*Upright	Phone	Standing while playing Subway Surf on a phone.
	Walking	Walking, at own pace, around a designated track.
†Break time	Free-play	10 min free-play during break time at school.

*Participants were directly observed to ensure the posture was as described

†The activPAL was used as a criterion measure of posture

5.2.4 Accelerometer data processing

All monitors were initialised, data downloaded and saved as described in Chapter 3, section 3.5. GENEActiv PC software version 3.1 was used to convert the raw format (binary files) to 15 s epoch .csv files, matching the format required for Sedentary Sphere analysis. The 15 s epoch files were then imported into custom-built Microsoft Excel spreadsheets (available on request) to facilitate computation of the most likely posture.

The AG raw format .gt3x files were converted to time-stamped .csv files (using ActiLife version 6.13.3) containing *x*, *y* and *z* vectors. These 100 Hz .csv files were subsequently converted with a custom-built programme (GT9X-to-SedSphere) written in MATLAB (R2017b, The MathWorks Inc., Natick, MA, USA) to 15 s epochs with the orientation of each axis matched to those of the GA. Thus, this matched the format required for the analysis in the custom-built Excel spreadsheets. The resultant 15 s epoch files contained *x, y* and *z* vectors (mean acceleration over the epoch, retaining the gravity vector) and vector magnitude values (summed over each epoch and corrected for gravity).

ActivPAL .datx files were converted to 15 s epoch .csv files using activPAL3 Professional Research Edition version 7.2.32.

5.2.5 Sedentary Sphere

The Sedentary Sphere calculates the most likely posture (sitting/reclining or upright) based on arm elevation and acceleration intensity (Rowlands et al., 2014). An arm elevation higher than 15º below the horizontal coupled with low intensity (< 489 g·15 s (value is specific to data collected at 100 Hz over a 15 s epoch), or 326 m*g* (value is sampling frequency and epoch independent)) is indicative of a seated/reclining position (Rowlands et al., 2016c), thus classified as “sedentary”. If the arm is hanging more vertically (lower than 15º below the horizontal), an “upright” (standing) posture is classified (Rowlands et al., 2016c). MVPA intensities (> 489g·15 s, or 326 m*g*) results in an “upright” classification, irrespective of wrist elevation (Rowlands et al., 2016c). During a free-living sample of 34 adults, agreement between GA (Sedentary Sphere) and activPAL was 85% (Rowlands et al., 2014). Another free-living study in adults (Pavey et al., 2016) found a strong, significant correlation (Pearson’s r = 0.81 (95% CI 0.69-0.88)) between estimated ST as measured by activPAL and GA (Sedentary Sphere).

5.2.6 Data analysis

After applying the Sedentary Sphere method to both GA and AG data, the percentage of epochs correctly coded as sedentary and upright during the gymnasium protocol (criterion: direct observation) and school break time (criterion: activPAL) were calculated for both the dominant and the non-dominant wrists. Percentages (i.e. accuracy) were summarized and presented as means (95% CI) for each individual activity. Pairwise 95% equivalence tests (±10%) and intra-class correlation coefficients (ICC, single measures, absolute agreement) were used to evaluate agreement of posture estimates between wrists and between accelerometer brands.

During the subsequent free-living study, the Sedentary Sphere method was applied to all valid hours collected from GA and AG monitors between 07:00 and 21:00 on the second day of data collection and in the same way, compared to results from activPAL. Hours were deemed invalid if the monitors were removed for any number of minutes during that hour, according to the log sheets. Visual inspection of data files in GA, AG and activPAL software verified the recorded log sheet wear times (Rowlands et al., 2016c). Thirty-one hours were excluded due to non-wear, while two participants' activPALs fell off resulting in another 18 hours being excluded. A total of 245 free-living hours across the whole sample were included in the analysis. Intra-individual classification agreement across 15 s epochs was reported as percentage agreement, sensitivity and specificity, and limits of agreement were examined using Bland-Altman analysis. Due to the presence of heteroscedasticity, Bland-Altman analysis were re-run using logarithmic transformation (Bland and Altman, 1999). Equivalency analysis was performed to assess average group level equivalence between AG and GA sedentary estimates according to the Sedentary Sphere method with the criterion being ST according to activPAL. An equivalence test was completed to establish whether the 90% confidence intervals for AG and GA ST fell within the zone of equivalence, defined as ±10% of the activPAL mean (Dixon et al., 2018). Mean percent error (MPE) and mean absolute percent error (MAPE) were calculated as described by DeShaw et al. (2018). In addition, for comparison a cut point approach was also applied to classifying ST. All free-living seconds with a corresponding accelerometer output of less than 50 m*g* were coded as sedentary, with all other seconds coded as non-sedentary. The resultant STs estimated by the 50 m*g* threshold for both GA and AG were compared with activPAL in the same way as the Sedentary Sphere results. Statistical analyses were performed using Microsoft Excel 2016 (Microsoft, Redmond, WA, USA).

5.3 Results

5.3.1 Sedentary stations and free-play during break time

Descriptive data for all participants are presented in Chapter 4 (Table 4.2). Twenty-seven participants (17 girls, 10 boys; 3 left-handed) completed all the stations in the school gymnasium, while 10 minutes of free-play (playtime) data for 25 participants were included in the analysis (two participants' activPALs fell off during school recess). Table 5.2 shows the mean (95% CI) percentage of 15 s epochs correctly coded as sedentary and upright for activities grouped by type and classification category, for each measurement method. During the protocol in the gymnasium, sedentary (lying and sitting) activities were correctly classified for the majority of the time (87-100%), except for TV viewing that had a slightly lower accuracy (66-71%).

Classification of walking as upright was accurate the vast majority of the time (87-90%), however 'standing while playing with a mobile phone' was misclassified as sitting for most of the time (≤ 12% accuracy). Free-play data during break time showed high classification accuracy (82-88%) relative to the activPAL, with the majority of epochs (99.5%) classified as upright. When the 'standing while playing with a mobile phone' activity was excluded from the analysis, accuracy increased across the board: from 77% to 87% for GA non-dominant wrist, 78% to 91% for GA dominant wrist, 78% to 90% for AG non-dominant wrist and from 79% to 91% for AG dominant wrist data (data not shown). During the observed activities, data from activPAL showed a 96.9% (SD = 4) agreement with direct observation.

Mean percent accuracy for the whole data collection period (observed and break time activities) was similar, irrespective of accelerometer brand, at 77%-78% for the non-dominant wrist and 79% for the dominant wrist. Posture estimates could be considered equivalent (Figure 5.1) between brands worn on the same wrist (± 5%, ICC > 0.84, lower 95% CI > 0.80, top panel of Figure 5.1), between wrists within brand (± 6%, ICC > 0.81, lower 95% CI ≥ 0.75, middle panel of Figure 5.1) and between brands worn on opposing wrists (± 6%, ICC ≥ 0.78, lower 95% CI ≥ 0.72, lower panel of Figure 5.1).

Table 5.2 Mean (95% confidence interval) percentage of epochs correctly coded as sedentary (lying and sitting activities) and upright for each activity and method (n = 27).

Activity Type	Individual Activities	Sedentary Sphere: GENEActiv data		Sedentary Sphere: ActiGraph data	
		Non-dominant	**Dominant**	**Non-dominant**	**Dominant**
Sedentary*	Rest	92.8 (85.4,100.0)	88.0 (78.0,98.0)	90.2 (81.7,98.7)	86.9 (76.4,97.5)
	TV	66.2 (49.9,82.5)	68.8 (52.6,85.1)	71.4 (55.6,87.2)	71.4 (55.3,87.5)
	Tablet	96.3 (89.1,100.0)	99.8 (99.3,100)	100 (100,100)	99.8 (99.3,100.2)
	Lego	92.2 (82.5,100.0)	98.7 (96.5, 100)	99.6 (98.7,100.0)	100 (100,100)
	Homework	89.8 (80.5,99.0)	99.6 (98.7,100.4)	93.9 (86.3,101.5)	99.6 (98.7,100.0)
Upright*	Phone	12.2 (0.1,24.3)	0 (0,0)	1.5 (0.0,3.5)	1.5 (0.0,4.6)
	Walking	87.4 (77.4,97.4)	90.4 (82.9,97.9)	86.5 (77.1,95.9)	90.4 (84.7,96.1)
	All observed activities	**76.7 (71.2,82.2)**	**77.9 (72.3,83.5)**	**77.6 (72.1,83.1)**	**78.5 (73.0,84.0)**
Break time†	Free-play	81.6 (73.1,90.1)	88.1 (83.3,92.9)	86.1 (80.5,91.6)	86.8 (81.3,92.3)
	Break time and observed activities	**77.3 (72.3,82.2)**	**79.1 (74.1,84.1)**	**78.6 (73.6,83.5)**	**79.5 (74.6,84.4)**

*Participants were directly observed to ensure the posture was as described

†The activPAL was worn to provide a criterion measure of posture

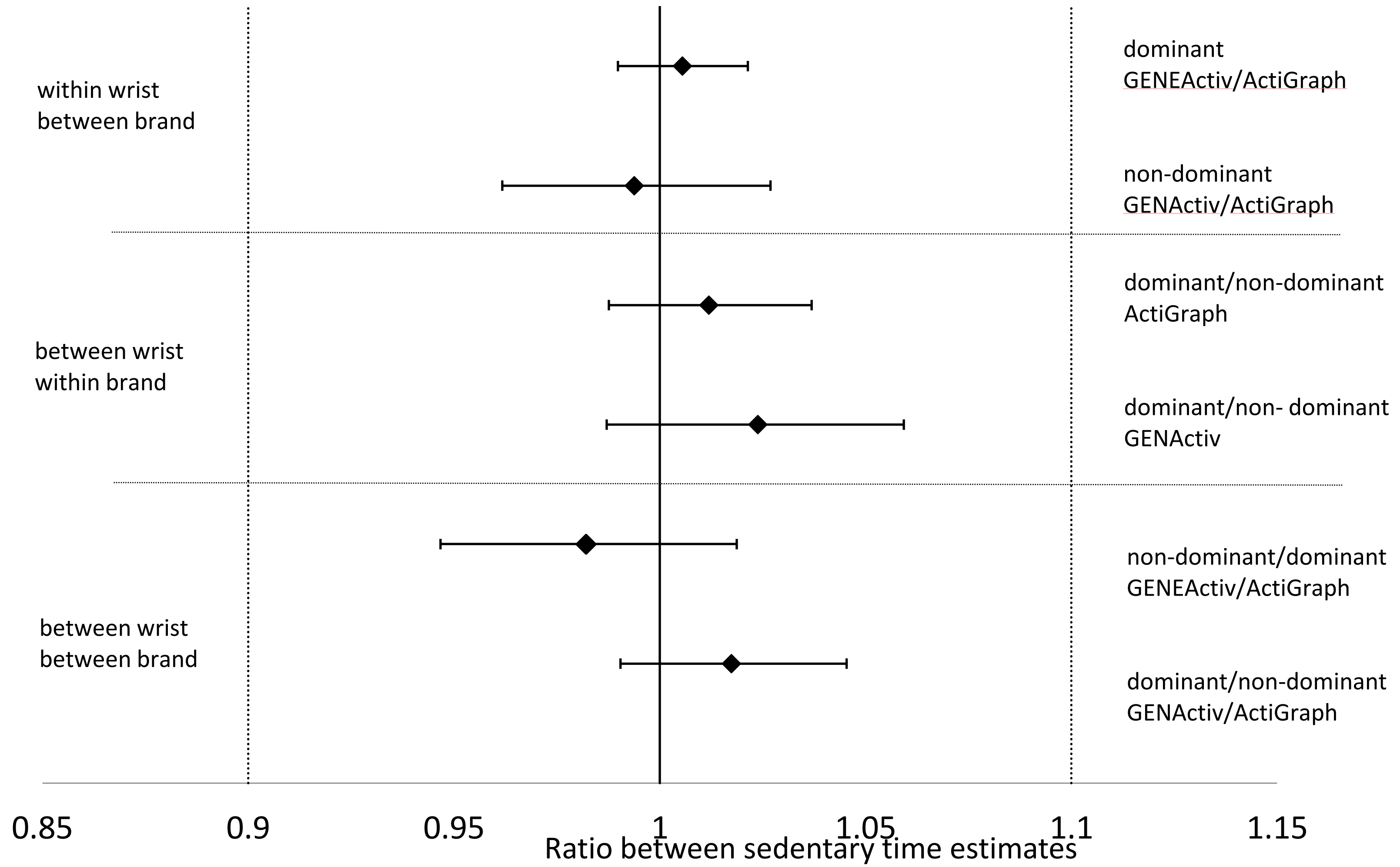


Figure 5.1 Equivalence between brands worn on the same wrist (top panel), between wrists within brand (middle panel) and between brands worn on opposing wrists (lower panel). Dashed vertical lines represent equivalence zone of ±10% of the mean.

5.3.2 Free-living sample

Free-living data from 21 participants (13 girls, 8 boys; 3 left-handed) were included in the analysis (see Chapter 4, Table 4.2 for descriptive data). Mean wear time was 700 ± 181 min (mean ± SD). Results from the various statistical analyses are presented in Table 5.3. According to activPAL, participants spent on average 67% of their time seated (468 ± 134 min). The corresponding estimates of ST according to the Sedentary Sphere were both lower (GA: 60%, 415 ± 138 min and AG: 58%, 407 ± 131 min). Mean (95% CI) intraindividual classification agreement between GA and activPAL across 15 s epochs was 77.3% (73.5, 81.1) with sensitivity at 77.2% (71.9, 82.6) and specificity 76.4% (72.2, 80.6). Figure 5.2 shows the log-transformed data: the mean bias of GA relative to activPAL was -0.06, with limits of agreement between -0.2 and 0.09 (Figure 5.2, top figure). Back-transformation (antilog) of the log-transformed data revealed that the GA 95% limits of agreement were 37.4% lower to 22.5% higher than activPAL.

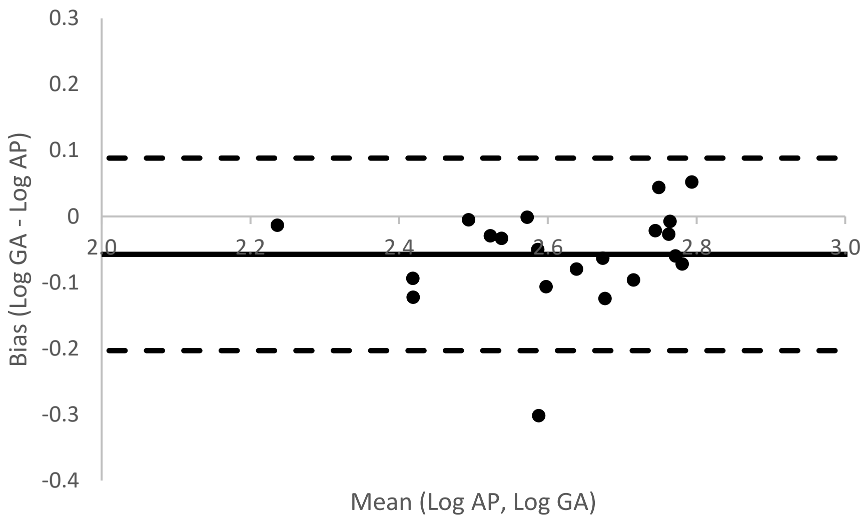
Agreement between AG and activPAL across 15 s epochs was similar to that observed for GA, at 76.7% (74.5, 79), sensitivity 75.4% (71.8, 78.9) and specificity 78% (73.7, 82.4). Mean bias (Figure 5.2, bottom figure) of log transformed data was also -0.06, but with narrower limits of agreement (-0.16 – 0.03, or 30.6% lower to 5.9% higher than activPAL). Results from the equivalence testing are displayed in Figure 5.3. Estimates of ST according to the Sedentary Sphere method applied to both GA and AG data could not be considered statistically equivalent when compared with the activPAL, on average at the group level. Extending the zone of equivalency to 15% of the activPAL mean still did not achieve equivalency with activPAL. While both monitors underestimated time spent sedentary compared with activPAL, GA came closer than AG to achieving equivalency with activPAL. This is confirmed in the MPE indicating underestimations of -11.3% (GA) and -13.7% (AG) against activPAL, and MAPE (GA = 13.5%, AG = 15.3%).

Table 5.3 and Figure 5.3 also display results from the comparison between activPAL and the 50 m*g* threshold. ST according to the threshold were significantly higher compared with activPAL (GA: 72%, 505 ± 114 min, $p = 0.001$; AG: 72%, 504 ± 144 min, $p = 0.002$). Mean bias and limits of agreement of log-transformed GA and AG 50 m*g* data relative to activPAL were similar (both with mean bias of 0.03, 95% limits of agreement 10% lower and 29% higher than activPAL). For both GA and AG 50 m*g* thresholds, equivalency with activPAL was achieved when the zone of equivalence was defined as 15% of the activPAL mean.

Table 5.3 Sedentary time estimates according to the sedentary sphere applied to AG and GA free-living data compared with activPAL

	Comparison	Mean (SD) minutes	Intraindividual classification agreement across 15s epochs [mean(95%CI)]			MAPE* (%)	MPE† (%)	Limits of Agreement†		Equivalency Analysis (minutes)
			Agreement (%)	Sensitivity (%)	Specificity (%)			Lower	Upper	
activPAL (sit/lie)		468 (134)								Zone of Equivalence: 422 – 515
	GENEActiv (Sed Sphere)	415 (138)	77.3 (73.5, 81.1)	77.2 (71.9, 82.6)	76.4 (72.2, 80.6)	13.5 (11.3)	-11.3 (13.6)	37.4%	22.5%	90% CI 389 – 441
	ActiGraph (Sed Sphere)	407 (131)	76.7 (74.5 , 79)	75.4 (71.8, 78.9)	78 (73.7, 82.4)	15.3 (6.9)	-13.7 (9.7)	30.6%	5.9%	90% CI 389 – 424
	GENEActiv (<50m*g*)	505 (144)				9.6 (8.7)	8.1 (10.2)	10.2%	28.9%	90% CI 489 – 521
	ActiGraph (<50m*g*)	504 (144)				9.5 (8.9)	7.8 (10.5)	10.9%	29.4%	90% CI 488 – 520

*Mean absolute percent error †Mean percent error †Log-transformed data back-transformed (antilog) and reported as percentages



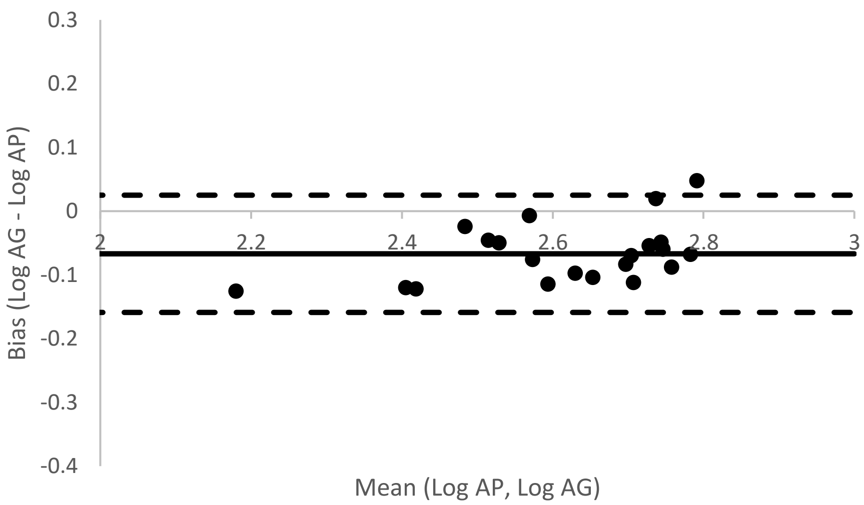


Figure 5.2 Mean bias (solid line) and 95% limits of agreement (dashed lines) for sedentary time estimated from the Sedentary Sphere posture algorithm applied to free-living GA (top figure) and AG log transformed data (bottom figure), relative to activPAL.

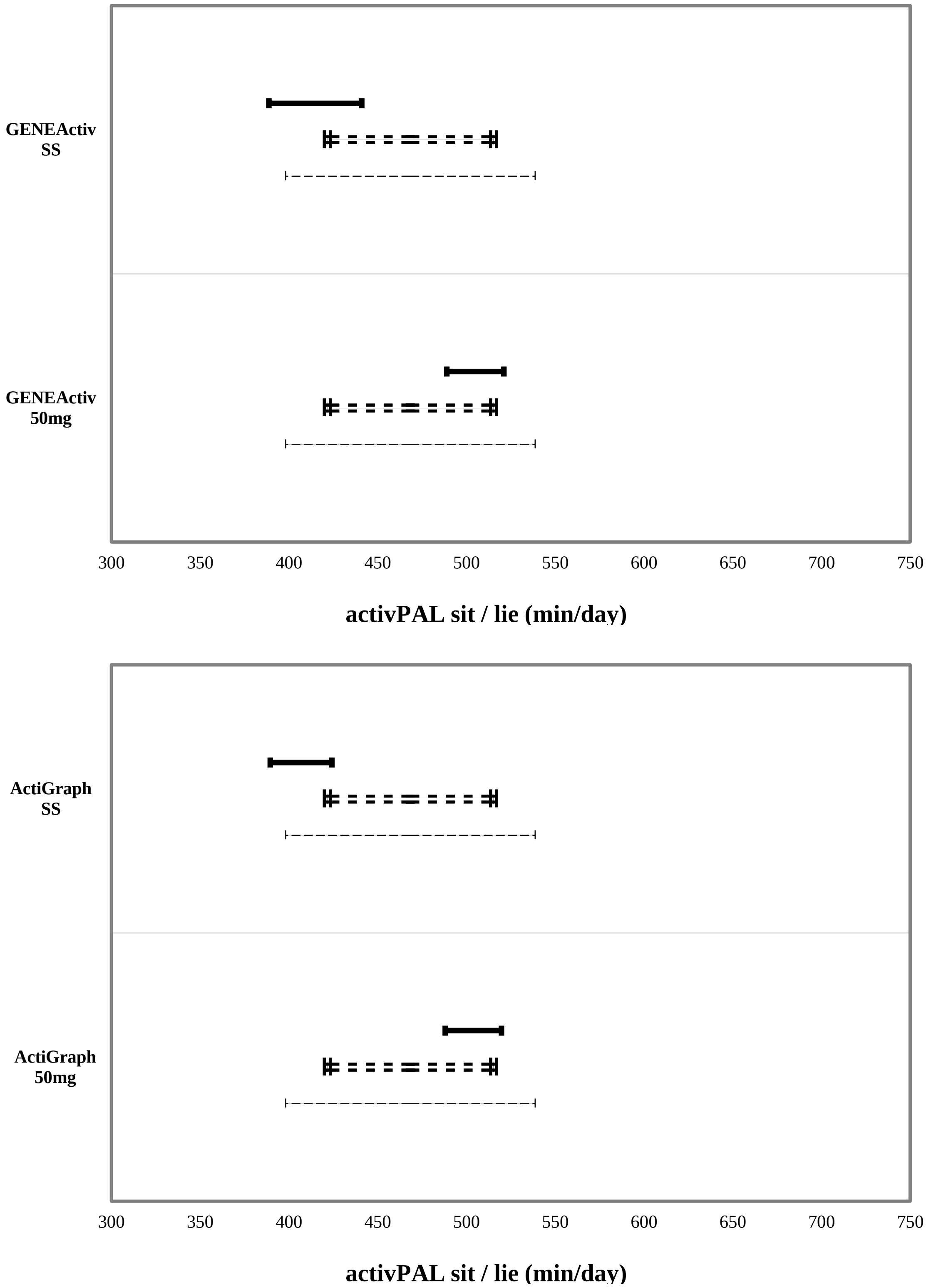


Figure 5.3 activPAL sedentary time zone of equivalence (10% = double-dotted lines, 15% = dotted lines) and 90% confidence intervals for the GENEActiv (top figure) and ActiGraph (bottom figure) sedentary time estimates according to the sedentary sphere (SS) and threshold (50 m*g*) methods.

5.4 Discussion

The aim of this study was to validate the Sedentary Sphere method of classifying posture using GA and AG GT9X wrist-worn accelerometers in children. Posture classification is vital to accurately measuring SB, though the majority of studies classify ST using low levels or an absence of acceleration according to thresholds, without considering posture. This study suggests that the Sedentary Sphere method can be used to classify the most likely posture in children (from either wrist-worn GA or AG accelerometers), but researchers should be cautious, knowing that the method is likely to underestimate ST. Wrist-worn accelerometers are increasingly being used to measure children's PA and SB (e.g. Keane et al., 2017), due to improved wear compliance in comparison to hip-worn devices (Fairclough et al., 2016), therefore the ability to classify posture using one wrist-mounted accelerometer is advantageous to researchers and funders.

Posture classification accuracy was high for most observed activities, during break time and the longer free-living period, irrespective of monitor brand or dominance (mean around 78%). This is higher than the 69% agreement reported between the widely used AG hip cut-point for ST (100 vertical-axis counts$\cdot$min^{-1}) compared with activPAL sitting time during the school day (Ridgers et al., 2012). During free-living time, the Sedentary Sphere applied to AG and GA data both underestimated sitting time compared with activPAL, however, classification accuracy during this period was consistent with the observed activities. The free-living results showed smaller mean bias and limits of agreement than those reported by Hildebrand et al. (2016) who compared sedentary cut-points with activPAL (smallest mean bias +30, LoA -226 to +287 min). While the activPAL has proven to be a valid tool to measure time spent sitting / lying, standing and walking (perfect correlation between activPAL and observation, r = 1.00) in children (Aminian and Hinckson, 2012), the step count becomes increasingly inaccurate as PA intensity increases (r = 0.21 to 0.34 for fast walking and running respectively) (Aminian and Hinckson, 2012). It is established that wrist-worn accelerometers can provide valid measures of PA in children (Phillips, Parfitt and Rowlands, 2013; Chandler et al., 2016). This study showed that posture can also be classified using data from wrist-worn accelerometers during structured low intensity activities, a period of free-play and free-living time. Further, this study shows that a wrist-worn GA or AG give equivalent estimates of ST by using the Sedentary Sphere method, irrespective of whether the monitor is worn on the dominant or non-dominant wrist. While previous research has shown acceleration magnitude for AG to be approximately 10% lower than that of GA (John et al., 2013; Rowlands et al., 2015), this study's findings are consistent with previous work suggesting that posture classifications based on orientation of the gravitational component compare well, irrespective of monitor brand (Rowlands et al., 2016b).

'Standing while playing with a mobile phone', was rarely correctly classified. The reason for the misclassification lies in the nature of the activity itself. It is a known limitation of the posture classification algorithm that any activity requiring the arms to be elevated while standing will be misclassified as sitting (Rowlands et al., 2016c). This will have implications in free-living studies, the extent of which will depend on the prevalence of standing with arms raised. Similar findings were observed in adult studies, with activities like waitressing (Pavey et al., 2016) or washing-up (Rowlands et al., 2014) misclassified as sitting. Participants typically held the phone with both hands, resulting in the elevation of both arms, causing the misclassification on both wrists. Standing still is notoriously difficult to classify from the magnitude of acceleration alone, as noted by Lyden and colleagues (Lyden et al., 2014), irrespective of whether counts per second or raw acceleration signals are examined, or whether laboratory or free-living settings are being investigated. As little or no dynamic acceleration is recorded during ST, devices cannot distinguish between sitting and standing still based on the magnitude of acceleration signals alone. To overcome large misclassifications, previous studies have chosen to group sitting and standing together (e.g. Mathie et al., 2004; Ermes et al., 2008), however, doing so contradicts the consensus definition of SB, that includes lying, reclining or sitting postures only (Tremblay et al., 2017). Notably, the Sedentary Sphere method accurately classifies standing still in adults (mean percentage accuracy = 100% for GA data, 95% for AG data) (Rowlands et al., 2016c), in structured conditions without the arms elevated.

During the free-play period, where children did not have access to mobile phones, upright postures were classified accurately most of the time, as is evident via the high percentage agreement with activPAL ($\geq$ 82%). The use of handheld devices, such as mobile phones, is prevalent; in a 2014 study, out of 8,266 nine-year-old Irish children, 41% had their own mobile phones (Lane, Harrison and Murphy, 2014) and access to mobile phones has increased dramatically over relatively short time periods (Kiatrungrit and Hongsanguansri, 2014). Potentially, mobile phone use could detrimentally effect the accuracy of the posture estimation; the impact of this will depend on whether children of this age spend a lot of time standing still with a mobile phone, or if they prefer to sit down or walk.

However, epoch-by-epoch agreement between both GA and AG non-dominant wrist data and activPAL during the subsequent free-living sample was the same (77%) as the accuracy reported during the observed activities and free-play period, superior to published results from counts-based cut-points (Ridgers et al., 2012). These are encouraging results, suggesting that the method performed equally well in an ecologically valid setting and in the controlled environment, where the aim was to mimic the typical range of activities children engage in during and after school hours. Equivalence testing, MPE and mean bias values of free-living data, however, showed that the method underestimated ST compared with activPAL, suggesting that while this method seems promising, the algorithms may require refinement for use in children to provide a more accurate estimate of SB. While the Sedentary Sphere method underestimated ST, the more traditional thresholds method slightly overestimated ST compared with activPAL.

This study has several strengths. The protocol included five different sedentary activities, one stationary activity and one LPA as well as 10 minutes of break time allowing free-play, thus a wide range of behaviours were represented. The independent free-living sample confirmed our observed activities had ecological validity, thus overcoming criticisms of previous validation studies. The participants wore five different monitors each, enabling us to validate the Sedentary Sphere method in both AG GT9X and GA monitors and across both wrists. We used direct observation as criterion measure for the protocol in the school gymnasium, with one trained researcher observing each participant. There were also some limitations. The small homogeneous sample of 9-10-year-old children should not be considered representative of all ages, and further studies are needed for younger children and older adults. The monitors were placed next to each other on the wrist, in no consistent or specific order. Placing one brand consistently distal to the other might have resulted in slightly higher acceleration from that brand; however, no formal randomisation techniques were used and recent studies in adults suggest that results are consistent, regardless of placement (Rowlands et al., 2018b). Though the stations were not performed in the same order no formal randomisation techniques were used, though unlike PA calibration studies, the sedentary and stationary nature of the stations should have avoided issues related to fatigue. During the free-living period, monitors were worn only on the non-dominant wrists in order to reduce participant burden.

5.5 Conclusions

This is the first study to apply the Sedentary Sphere classification algorithm to children's data. The results suggest the method developed in adults can be applied to wrist-worn accelerometer data to predict the *most likely* posture in children, but the algorithm needs refining for child populations. Results found that the Sedentary Sphere was equally valid for GA and AG GT9X accelerometers, whether the monitor was worn on the dominant or non-dominant wrist, and agreement with activPAL was confirmed during the free-living sample. However, the method underestimated free-living ST and future work should ideally use direct observation during free-living time, or simulated free living, to identify where misclassification occurs. This will allow for further work on improving the algorithm for child populations in order to achieve better results on individual level estimates. Improvements might include adding new features like patterns of movement within angles, patterns of changes in angles or adding a frequency domain.

Thesis study map

Study	Aims and key findings
Study 1: Establishing raw acceleration thresholds to classify sedentary and stationary behaviours in children	**Aims:** 1. To compare the raw accelerometer output of ActiGraph (AG) and GENEActiv (GA) accelerometers across different placements, 2. To identify raw acceleration signal thresholds for different sedentary behaviours in children, from both the hip and wrist, using AG and GA, 3. To validate the thresholds during free-living activities. **Key findings:** • Hip worn AG monitors resulted in significantly lower acceleration output compared to wrist worn monitors, and are not comparable. • Statistically significant differences between accelerometer outputs of sedentary activities were observed, however these differences are unlikely to be meaningful in practice. • Inconsistent differences between GA and AG monitors were observed during calibration, however free-living data confirmed that the differences were small and unlikely to be meaningful in practice. • Sedentary and stationary thresholds were developed for AG hip, AG and GA non-dominant and dominant wrist placements. • The sedentary thresholds slightly overestimated free-living sedentary time compared with activPAL. The stationary thresholds underestimated stationary time according to activPAL.
Study 2: Validating the Sedentary Sphere method in children.	**Aims:** 1. To validate the Sedentary Sphere method of classifying posture, in child populations using GENEActiv and ActiGraph GT9X wrist-worn accelerometers

	Key findings: • During most observed activities posture classification was high (~78%), irrespective of brand or placement. • "Standing with phone" was misclassified most of the time. • Classification accuracy during free-living was consistent with observed activities (77%), but the method underestimated sitting time compared with activPAL.
Study 3: Exploring a novel mixed-methods approach to assess children's sedentary behaviours.	**Aims:** 1. To explore the efficacy of using accelerometry in combination with a digitalised data capture tool, the Digitising Children's Data Collection (DCDC) for Health, in order to capture children's SBs more comprehensively.
Study 4: Parental perceptions of the factors influencing children's sedentary behaviours.	

CHAPTER 6

STUDY 3

EXPLORING A NOVEL MIXED METHOD APROACH TO ASSESS CHILDREN'S SEDENTARY BEHAVIOURS

The main outcomes of this study have been accepted for publication in *Journal for the Measurement of Physical Behaviour:* Hurter, L., Cooper-Ryan, A.M., Knowles, Z.R., Porcellato, L.A., Fairclough, S.J. and Boddy, L.M. (2020). Exploring a novel mixed methods approach to assess children's sedentary behaviours. *Journal for the Measurement of Physical Behaviour*, 3(1), 78-83.

6.1 Introduction

Accurate assessment of SB in children is notoriously difficult to achieve (Lubans et al., 2011; Hardy et al., 2013), due mainly to the complexity of the behaviour itself. Self-report questionnaires (or in the case of young children, proxy-report by a parent/carer) are often used to measure SB (Lubans et al., 2011; Atkin et al., 2012). However, self- and proxy-report tools are known to be susceptible to recall errors, misrepresentations and social desirability (Loprinzi and Cardinal, 2011; Atkin et al., 2012; Hardy et al., 2013). Accelerometry has become a widely accepted device-based method of measuring SB (Atkin et al., 2012; Cain et al., 2013), with researchers now able to use population-specific raw acceleration cut-points as developed during Study 1 (Chapter 4) to classify ST, and/or the Sedentary Sphere method to predict the most likely posture from wrist-worn devices (Study 2, Chapter 5). One of the limitations of accelerometry however, is its inability to provide any *context* about the type of behaviour or settings in which the behaviours occur. Rich, contextual data would include type of activity (e.g. screen time, reading, homework etc.), whether children are alone or interacting with other people (e.g. friends, siblings or parents/carers) and the settings where the behaviours occur (e.g. home, car, school). Currently, DO is the only tool that can provide researchers with this type of information, and has successfully been used to report behaviours in restricted areas during short time periods (e.g. school playgrounds during break time (Roberts et al., 2013)). However, direct observation is labour intensive, expensive and not feasible in a free-living context. In adult studies, (e.g. Kim and Kang, 2019) wearable cameras have successfully been used as a criterion measure of a direct observation proxy. However, due to various ethical considerations (Kelly et al., 2013) this is not feasible in children. Indeed, Lubans et al. (2011) recommend that a mix of methods be used to estimate SB in children. More recently, researchers investigating associations between SB and academic performance also called for studies to use both accelerometry and self-report tools in order to differentiate between academic-based- (e.g. reading, homework) and screen-based SB (Syväoja et al., 2013; Lima et al., 2019). According to Lima et al. (2019), a lack of contextual information has, in the past, prevented researchers from evaluating the association between SB and academic performance. Moreover, researchers need to differentiate between different forms of screen time, as recent evidence suggests that television viewing for example is related to obesity (Stiglic and Viner, 2019), but there is currently insufficient evidence to conclude the same relationship exists with other forms of screen time (e.g. computers, video games, mobile phone use).

The present study aimed to explore the efficacy of using accelerometry in combination with a digitalised data capture tool called the Digitising Children's Data Collection (DCDC) for Health (Cooper and Dugdill, 2014), in order to capture SB more comprehensively. The DCDC application (app) was developed at the University of Salford, UK to allow flexible data collection with primary school aged children via tablets across multiple settings, using a mixed-methods approach. DCDC may therefore enable the capture of contextual data that is lacking when using accelerometry alone.

The app can be used within diverse settings and to collect data over a longer period of time than is currently possible with traditional self-report questionnaires which would require repeat administration by a researcher. Whilst paper-based methods that ask children to recall their behaviour over the previous week are typically used in a school setting, giving children a tablet enables them to report their behaviour through photos, drawings and voice recordings at home or wherever they go. Asking children to self-report their SB on a daily basis, as opposed to trying to remember what they did the previous week, could reduce recall errors. The app is deemed suitable for children aged 5 – 11 (Cooper and Dugdill, 2015), and can be adapted according to the specific abilities of the age range studied. For example, voice recordings can ask questions to children unable to read. Combining the DCDC app with accelerometry, this study aimed to explore whether the app can capture the rich, contextual data about children's SB that has been absent in the literature until now. Knowing *what* types of SB children engage in and the settings in which these behaviours occur, together with time spent sedentary (according to accelerometry) would help researchers identify specific behaviours to influence intervention design.

6.2 Methods

6.2.1 Participants

Participants were recruited as described in Chapter 3 (section 3.2). 74 Year 5 children (9-11-years-old, 45 girls) from four primary schools provided signed informed parental consent and child assent forms (response rate = 82%), and were thus included in the study. Rolling recruitment and data collection took place between November 2017 and June 2018. The researcher had one contact session with participants in each school prior to the start of data collection, which was used for anthropometric measurements (as described in Chapter 3, section 3.4), explanation and fitting of accelerometers and familiarisation with the DCDC app on the tablet. Demographic information was obtained via demographic information forms and results calculated as described in Chapter 3, section 3.3.

6.2.2 Sedentary behaviour

Participants wore an AG GT9X accelerometer on their non-dominant wrist and were asked to wear it $24hr.d^{-1}$ for seven consecutive days. They were instructed to remove the monitor only for water-based activities (e.g. swimming, bathing) or contact sports (e.g. rugby). Participants were given a log sheet (paper based) to record any times and reasons they removed the monitors.

Each participant also received a Samsung Galaxy Tab4 (SM-T230) tablet, with the DCDC app installed (Cooper and Dugdill, 2014). Each tablet had a unique asset number, enabling the researcher to link the data captured by each tablet to the relevant participant. The DCDC app for Health consists of two applications, a Supporting Server Application (SSA) and a Tablet application (TA). The SSA (a remotely installed web application) allows researchers to design and build their own studies, using a mixed-methods approach. Further, the SSA manages and stores data flowing to and from the TAs. Prior to data collection, the researcher designed and built a SB study using the SSA and downloaded the study onto the TA on each Samsung tablet. In order to prevent children from using the tablets for longer than necessary, only the DCDC app was accessible, with all other applications password protected. Internet access was also blocked, preventing children from accessing online content.

The app uses four types of data collection tools: 1) Answer some questions, 2) Take and explain a photograph, 3) Draw and explain a picture and 4) Record my voice. Participants were asked to open the app once per day (suggested as towards the end of the day) and report their SB, by answering the pre-set questions in each tool. Once one of the tools was opened and answered, that tool was greyed out and the child could only access it again the next day. The first tool, "Answer some questions", consisted of six multiple-choice questions regarding behaviours outside of school time. The questions were adapted from the SB section of the Youth Activity Profile (Saint-Maurice and Welk, 2015). The second tool, "Take a photograph", asked the child "Can you take a photograph of any activities you did while sitting or lying down today?", and allowed a photo to be taken with the tablet's built-in camera. Children were instructed not to take any photographs of people, but rather of places / settings they spent time in. After taking a photo, children were given the option to save their photo and either to write something about their photo or describe their photo with a voice recording. The "Draw a picture" tool asked children the question: "Can you draw a picture of any activity you did while sitting or lying down today?" Children used their fingers to draw on the screen and could choose between different brush sizes and colours. Once saved, they were given the opportunity to write or talk (record their voice) about their drawing. Finally, the "Record your voice" tool asked participants to answer two questions: "Can you tell us what you did this morning?" and "Can you tell us what you did this afternoon?" During the familiarisation session, children were instructed to answer these questions by reflecting on their out-of-school time, i.e. in the mornings before school, and afternoons after school. A short video with a more detailed explanation of how the app works can be viewed using this link: https://youtu.be/LuvuUPGaqfY

After seven days of data collection, all tablets, accelerometers and log sheets were returned to school for collection. The results synchronised automatically with the SSA when connected to WiFi. Once synchronised, one study could be ended by removing the data from the tablet and allowing the study to be downloaded again for the next round of participants, using the same tablets but with new participant numbers. Audio files from voice recordings were transcribed verbatim. Participant profiles were created for each participant using a template, with their photos, drawings, voice recordings and multiple-choice answers, all of which were time and date stamped. For each tool, activities photographed, drawn or mentioned by the participants in voice recordings were grouped into different categories for analysis (e.g. television, computer / laptop, reading, playing with toys) and reported as frequencies. Whenever a photo, drawing or recording was unclear, researchers referred to the data from the other tools on that particular day and for most of the time, this triangulation of data clarified the uncertainty.

6.2.3 Accelerometer data processing and analysis

The AG accelerometers were initialised to collect data at 100Hz. After each data collection session, the 7-day files were downloaded and saved as described in Chapter 3, section 3.6. Data were analysed using both R-package GGIR (Migueles et al., 2019) (see Chapter 3, section 3.6 for details) and the Sedentary Sphere (Rowlands et al., 2014). As the participants kept the monitors on while sleeping, GGIR was used to report the full 24-hour activity behaviour profiles, which include the following: time in bed (sleep), time spent sedentary per day (threshold defined as waking time accumulated below 50 m*g* as developed during Study 1), MVPA per day (defined as time accumulated above 200 m*g* (Hildebrand et al., 2014)), average acceleration across the day (ENMO, m*g*) and intensity gradient as described by Rowlands et al. (2018a). These were all broken down into weekdays, weekend days and whole week data. Inclusion criteria for raw data analysis were at least 16 hours of wear time per day (Rowlands et al., 2018b) for at least four days (including at least 1 weekend day) (Trost et al., 2000).

The Sedentary Sphere method (Rowlands et al., 2014) was applied to all participants' data included in the raw acceleration data analysis, who also had completed their log sheets, in order to get an indication of the amount of time spent sitting, as the above mentioned thresholds are unable to differentiate between postures. The Sedentary Sphere calculates the most likely posture (sitting/lying or standing) for every 15 s of data, based on arm elevation and acceleration intensity (Rowlands et al., 2016c). As SB was the outcome of interest for this study, the Sedentary Sphere method was applied to waking hours only, while sleep and non-wear for the Sedentary Sphere analysis were deleted according to participants' individual log sheets. Differences between boys and girls, weekday and weekend data were examined using paired t-tests and effect sizes calculated as Cohen's *d* (Cohen, 1988) with 0.2, 0.5 and 0.8 defined as small, medium and large effects. Analysis was completed using IBM SPSS Statistics v.24 (IBM, Armonk, NY) with level of statistical significance set at $p \leq 0.05$ and Microsoft Excel 2016 (Microsoft, Redmond, WA).

6.3 Results

Figure 6.1 is a flow diagram showing participants included and excluded from each step of the analysis. Descriptive characteristics of all participants are presented in Table 6.1. Compliance from the 65 participants included in the raw acceleration data analysis was high with 52 (80%) full datasets (i.e. 7 valid days), 9 consisting of 6 valid days, 3 with 5 valid days each and 1 dataset of 4 valid days. Children mostly removed the monitors when taking a bath or shower, swimming or for sports like rugby, gymnastics or martial arts.

Table 6.2 shows results from the accelerometer data analysis, separated into weekdays and weekend days, while Table 6.3 shows differences between boys and girls. Participants spent on average 629 min (almost 10.5 hours) of their waking time per day sedentary. Time spent sedentary on weekend days was significantly higher than weekdays (652 min ± 78.27 vs 619.88

min ± 57.11; $p<0.001$; Cohen's $d = 0.47$). There were no significant differences found between boys' and girls' sedentary times (weekdays: $p = 0.58$, weekends: $p = 0.78$).

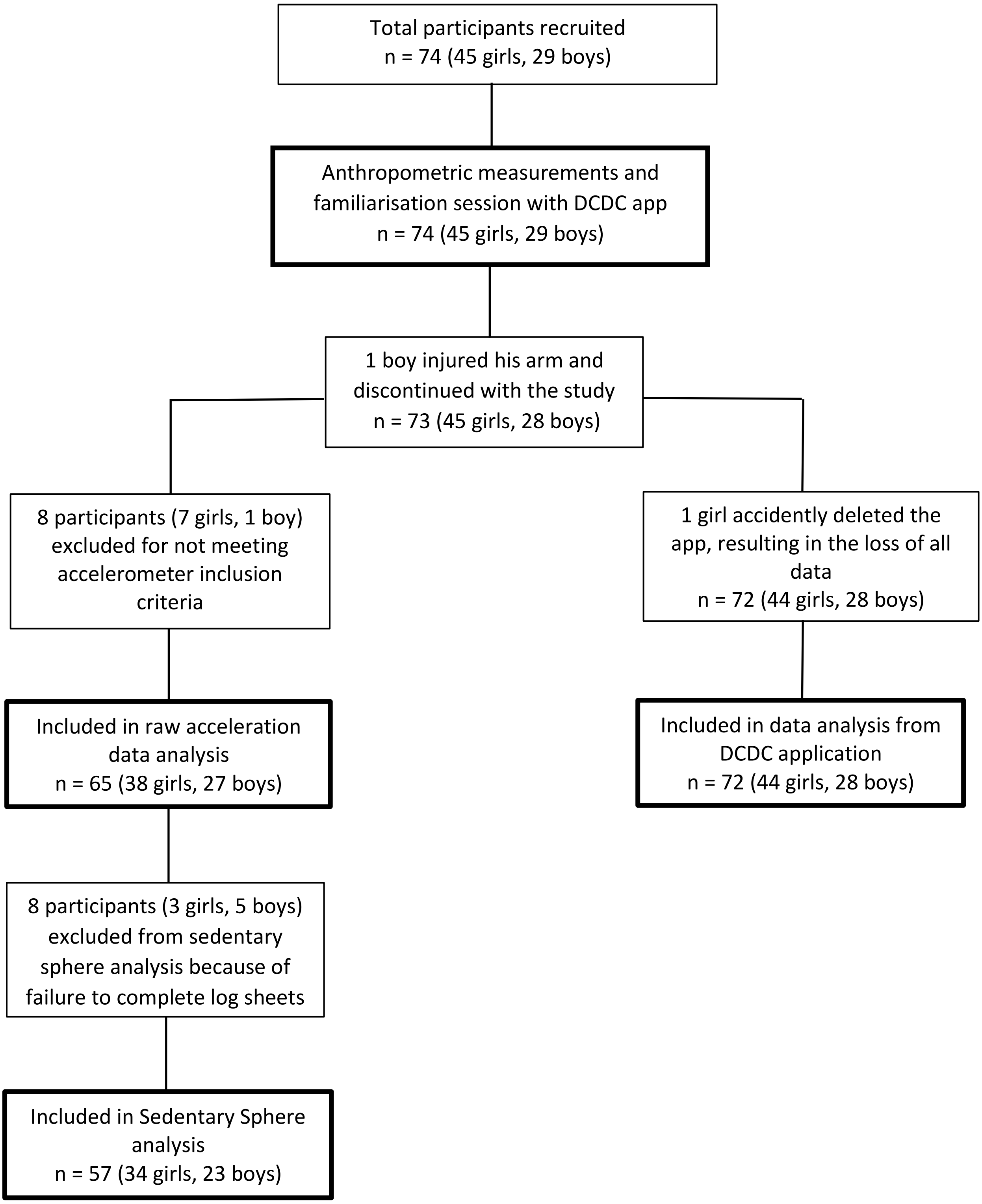


Figure 6.1 Flow diagram of participants

Table 6.1 Descriptive characteristics for all participants (n=74, expressed in Means (SD))

	Boys (n=29)	**Girls (n=45)**	**All (n=74)**
Age (years)	9.9 (0.4)	10 (0.4)	10 (0.4)
Height (cm)	140.8 (9.6)	139.8 (6.9)	140.2 (8.1)
Body mass (kg)	37.8 (12.5)	36.6 (8.5)	37.1 (10.2)
BMI (kg/m^2)	18.6 (4.0)	18.6 (3.2)	18.6 (3.5)
Waist circumference (cm)	65.7 (10.2)	65.5 (8.2)	65.6 (8.9)
APHV* (years)	13.5 (0.6)	11.7 (0.4)	12.5 (0.9)
Maturity offset	-3.6 (0.7)	-1.7 (0.5)	-2.5 (1.1)
Ethnicity (n, %)			
White (UK)			53 (71.6)
Mixed			13 (17.6)
White (other)			3 (4.1)
Chinese			4 (5.4)
Asian (Indian)			1 (1.4)
SES†			3 (2.6)

*Predicted Age at Peak Height Velocity
† SES is measured by the Index of Multiple Deprivation decile score, where 1 is the most deprived and 10 the least deprived

Results from the intensity gradient metric showed a significantly lower (steeper) gradient over weekends compared to weekdays ($p < 0.001$, $d = 0.96$). On average, girls had significantly lower (steeper) intensity gradients than boys (whole week: $p = 0.001$, $d = 0.9$; weekdays: $p = 0.001$, $d = 0.88$; weekend days: $p = 0.009$, $d = 0.7$). Results from the Sedentary Sphere suggest that the participants spent on average 48% of their waking time in seated / lying postures.

Contextual data provided by 72 participants via the app were included in the analysis. Only 9 children had full datasets, i.e. their results included 7 photos, 7 drawings, 14 voice recordings and the multiple choice questionnaire answered on all 7 days. One of the full datasets, however, had 10 blank audio files (from the "Record my voice" tool). On average participants answered the questions on the app typically around seven o'clock in the evening, with the exception of 17 cases where questions were answered before ten o'clock in the morning. These were excluded from the analysis, as it is uncertain whether the child was reporting his/her behaviour from earlier that morning or perhaps the previous day.

Table 6.2 Sedentary behaviour and Physical Activity outcomes for weekday and weekend data (n=65)

	Weekday data		Weekend data		Whole week (weighted week)	
	Mean minutes (SD)	**95% CI Lower - Upper**	**Mean minutes (SD)**	**95% CI Lower - Upper**	**Mean minutes (SD)**	**95% CI Lower - Upper**
Mean ENMO [m*g*]	49.73 (15.47)	45.89 – 53.56	36.58 (17.56)	32.23 – 40.94	45.91 (15.23)	42.14 – 49.69
Sleep	563.17 (40.98)	553.02 – 573.33	556.36 (55.26)	542.67 – 570.05	561.19 (37.77)	551.84 – 570.56
Sedentary time*	619.88 (57.11)	605.73 – 634.03	652.0 (78.27)[†]	632.61 – 671.4	629.19 (51.28)	616.49 – 641.90
LPA	172.64 (29.65)	165.28 – 180.0	155.36 (46.65)	143.8 – 166.92	167.63 (30.01)	160.19 – 175.07
MPA	48.18 (14.63)	44.56 – 51.81	41.74 (22.97)	36.05 – 47.44	46.31 (15.56)	42.46 – 50.17
VPA	13.05 (7.49)	11.19 – 14.90	8.56 (9.33)	6.25 – 10.87	11.74 (7.64)	9.85 – 13.64
MVPA	61.24 (20.74)	56.1 – 66.38	50.29 (30.96)	42.63 – 57.97	58.06 (22.03)	52.61 – 63.52
Intensity regression line						
Intensity gradient	-1.96 ± 0.14		-2.11 ± 0.17		-2.01 ± 0.13	
Sedentary Sphere						
Sit/Lie[¥]	48.07% (10.15)		48.03% (14.78)		48.06% (11.66)	

*threshold = <50m*g* [†]significantly higher than weekday data

[¥] n = 57, % of waking time included in analysis spent in sitting/lying postures

Table 6.3 Sedentary behaviour and Physical Activity outcomes for boys (27) and girls (38)

	Weekday data (mean (SD))		**Weekend data (mean (SD))**		**Whole week (weighted week)**	
	Boys	**Girls**	**Boys**	**Girls**	**Boys**	**Girls**
Mean ENMO [m*g*]	57.56 (16.86)	43.95 (11.63)	42.4 (22.22)	32.45 (12.0)	53.08 (17.64)	40.62 (10.71)
Sleep	560.5 (35.9)	565.07 (44.62)	548.46 (50.43)	561.97 (58.46)	557.01 (31.35)	564.17 (41.9)
Sedentary time*	614.45 (40.38)	623.03 (66.88)	655.43 (86.24)	649.57 (73.18)	627.04 (43.96)	630.72 (56.44)
LPA	172.52 (33.86)	172.73 (26.83)	155.63 (49.82)	155.18 (44.95)	167.62 (32.82)	167.64 (28.31)
MPA	53.99 (14.59)	44.06 (13.37)	48.28 (27.6)	39.09 (18.0)	52.34 (16.67)	42.04 (13.36)
VPA	17.23 (8.28)	10.08 (5.19)	11.64 (12.51)	6.37 (5.38)	15.61 (9.07)	9.0 (4.94)
MVPA	71.23 (21.02)	54.13 (17.59)	59.91 (38.27)	43.47 (22.66)	67.95 (24.17)	51.04 (17.52)
Intensity regression line						
Intensity gradient	-1.89 (0.11) [†]	-2.01 (0.14)	-2.05 (0.18) [†]	-2.16 (0.15)	-1.94 (0.12) [†]	-2.05 (0.12)
Sedentary Sphere						
Sit/Lie[¥]	48.83% (10.68)	47.56% (9.78)	51.81% (17.12)	45.47% (12.48)	49.68 (12.87)	46.96 (10.64)

*threshold = <50m*g* [†] significantly lower than girls

[¥] boys n = 23, girls n = 34; % of waking time included in analysis spent in sitting/lying posture

The first data capturing tool, “Answer some questions”, was the preferred option of the four methods, with participants answering at least some of the questions on average 5.3 (SD=1.7) days during the 7-day period of data collection. The different questions were answered between 377 and 383 times by the participants (out of a possible 504). The app allows participants to go to the next question without answering the one on their screen, therefore not all questions were answered the same number of times.

Results from this tool are displayed in Tables 6.4 – 6.6. Table 6.4 shows the number of days each answer was given, broken down into weekdays and weekend days, while Table 6.5 shows the differences between boys’ and girls’ answers (in number of days). Table 6.6 shows only the answers from screen-based behaviours, specifically how many participants chose each answer, and its weekly average. Results indicated an increased amount of television viewing on weekend days compared to weekdays (Table 6.4), with a 10% reduction in the number of children reporting not watching any TV during weekend days (25%) as opposed weekdays (35%). The same trend was observed for playing video games, with all answers indicating an increased amount of time playing video games during weekend days. Children reported not using a computer at all on 63.9% of days and not using a mobile phone at all on 244 (63.9%) days (Table 6.6). There was limited active travel on school days with the majority of participants in this study traveling to school by car (59.9% of days reported). The biggest difference between boys and girls was observed in playing video games (Table 6.5). Boys reported on 12.2% of days (17/139) to have spent more than three hours playing video games, as opposed to girls reporting the same behaviour on only 2.5% of days (6/243).

Table 6.4 Answers from the multiple choice questionnaire ("Answer some questions") of the DCDC application (n = 72)

	Answers to multiple choice questions (Number of days (%))		
	Weekdays N (%)	**Weekend days N (%)**	**Total N (%)**
Question 1: How much time did you spend watching TV outside of school today?			
I didn't watch TV at all	100 (35.2)	25 (25.3)	125 (32.6)
I watched less than one hour today	97 (34.2)	30 (30.3)	127 (33.2)
I watched one to two hours today	53 (18.7)	28 (28.3)	81 (21.1)
I watched two to three hours today	14 (4.9)	4 (4)	18 (4.7)
I watched more than three hours today	20 (7)	12 (12.1)	32 (8.4)
Question 2: How much time did you spend playing video games outside of school today?			
I didn't really play at all	155 (54.8)	41 (41.4)	196 (51.3)
I played less than one hour today	62 (21.9)	27 (27.3)	89 (23.3)
I played one to two hours today	42 (14.8)	17 (17.1)	59 (15.4)
I played two to three hours today	9 (3.1)	6 (6.1)	15 (3.9)
I played more than three hours today	15 (5.3)	8 (8.1)	23 (6)
Question 3: How much time did you spend using a computer outside of school today?			
I didn't really use a computer at all	183 (64.9)	61 (61)	244 (63.9)
I used a computer less than one hour today	57 (20.2)	25 (25)	82 (21.5)
I used a computer one to two hours today	23 (8.2)	8 (8)	31 (8.1)
I used a computer two to three hours today	6 (2.1)	2 (2)	8 (2)
I used a computer more than three hours today	13 (4.6)	4 (4)	17 (4.5)
Question 4: How much time did you spend using a mobile phone today?			
I didn't really use a mobile phone	185 (65.3)	57 (57.5)	242 (63.4)
I used a phone less than one hour today	50 (17.7)	24 (24.2)	74 (19.4)
I used a phone one to two hours today	16 (5.7)	5 (5.1)	21 (5.5)
I used a phone two to three hours today	17 (6)	6 (6.1)	23 (6)
I used a phone more than three hours today	15 (5.3)	7 (7.1)	22 (5.7)

	Weekdays N (%)	Weekend days N (%)	Total N (%)
Question 5: Which of the following best describe your typical sedentary habits at home?			
I spent almost none of my free time sitting	47 (16.7)	19 (19.4)	66 (17.4)
I spent a little of my free time sitting	101 (36)	32 (32.7)	133 (35.1)
I spent a moderate amount of my time sitting during my free time	59 (21)	25 (25.5)	84 (22.2)
I spent a lot of time sitting during my free time	31 (11)	9 (9.2)	40 (10.5)
I spent almost all of my free time sitting	43 (15.3)	13 (13.2)	56 (14.8)
Questions 6: How did you travel to school today?			
Bus	4 (1.4)	0 (0)	4 (1.1)
Train	4 (1.4)	1 (1)	5 (1.3)
Bicycle	6 (2.2)	0 (0)	6 (1.6)
Walk	77 (27.6)	5 (5.1)	82 (21.8)
Car	167 (59.9)	13 (13.3)	180 (47.7)
I didn’t go to school today	9 (3.2)	77 (78.6)	86 (22.8)
Bus and car	2 (0.7)	0 (0)	2 (0.5)
Car and Walk	9 (3.2)	1 (1)	10 (2.7)
Car and I didn’t go to school today	1 (0.4)	0 (0)	1 (0.3)

Notes: Question 1 – 383 days in total: 284 weekdays, 99 weekend days
Question 2 and Question 4 – 382 days in total: 283 weekdays, 99 weekend days
Question 3 – 382 days in total: 282 weekdays, 100 weekend days
Question 5 – 379 days in total: 281 weekdays, 98 weekend days
Question 6 – 377 days in total: 279 weekdays, 98 weekend days

Table 6.5 Boys' (n=28) and girls' (n=44) answers from the multiple-choice questionnaire ("Answer some questions") of the DCDC application

	Answers to multiple-choice questions (Number of days (%))		
	Boys	**Girls**	**Total (%)**
Question 1: How much time did you spend watching TV outside of school today?			
I didn't watch TV at all	51 (36.7)	74 (30.3)	125 (32.6)
I watched less than one hour today	47 (33.8)	80 (32.8)	127 (33.2)
I watched one to two hours today	32 (23)	49 (20.1)	81 (21.1)
I watched two to three hours today	1 (0.7)	17 (7)	18 (4.7)
I watched more than three hours today	8 (5.8)	24 (9.8)	32 (8.4)
Question 2: How much time did you spend playing video games outside of school today?			
I didn't really play at all	61 (43.9)	135 (55.6)	196 (51.3)
I played less than one hour today	32 (23)	57 (23.5)	89 (23.3)
I played one to two hours today	24 (17.3)	35 (14.4)	59 (15.4)
I played two to three hours today	5 (3.6)	10 (4)	15 (3.9)
I played more than three hours today	17 (12.2)	6 (2.5)	23 (6)
Question 3: How much time did you spend using a computer outside of school today?			
I didn't really use a computer at all	84 (60.4)	160 (65.8)	244 (63.9)
I used a computer less than one hour today	23 (16.5)	59 (24.3)	82 (21.5)
I used a computer one to two hours today	14 (10.1)	17 (7)	31 (8.1)
I used a computer two to three hours today	7 (5)	1 (0.4)	8 (2)
I used a computer more than three hours today	11 (8)	6 (2.5)	17 (4.5)
Question 4: How much time did you spend using a mobile phone today?			
I didn't really use a mobile phone	96 (69.1)	146 (60.1)	242 (63.4)
I used a phone less than one hour today	26 (18.7)	48 (19.8)	74 (19.4)
I used a phone one to two hours today	7 (5)	14 (5.7)	21 (5.5)
I used a phone two to three hours today	6 (4.3)	17 (7)	23 (6)
I used a phone more than three hours today	4 (2.9)	18 (7.4)	22 (5.7)

	Boys	Girls	Total (%)
Question 5: Which of the following best describes your typical sedentary habits at home?			
I spent almost none of my free time sitting	29 (20.9)	37 (15.4)	66 (17.4)
I spent a little of my free time sitting	47 (33.8)	86 (35.8)	133 (35.1)
I spent a moderate amount of my time sitting during my free time	33 (23.7)	51 (21.3)	84 (22.2)
I spent a lot of time sitting during my free time	15 (10.8)	25 (10.4)	40 (10.5)
I spent almost all of my free time sitting	15 (10.8)	41 (17.1)	56 (14.8)
Questions 6: How did you travel to school today?			
Bus	1 (0.7)	3 (1.2)	4 (1.1)
Train	1 (0.7)	4 (1.7)	5 (1.3)
Bicycle	4 (2.8)	2 (0.8)	6 (1.6)
Walk	42 (30.9)	40 (16.6)	82 (21.8)
Car	51 (37.5)	129 (53.5)	180 (47.7)
I didn’t go to school today	29 (21.3)	57 (23.7)	86 (22.8)
Bus and car	0 (0)	2 (0.8)	2 (0.5)
Car and Walk	7 (5.4)	1 (0.4)	10 (2.7)
Car and I didn’t go to school today	1 (0.7)	0 (0)	1 (0.3)

Notes: Question 1 – 383 days in total: boys’ answers totalled 139 days, girls’ 244 days
Question 2, 3 and 4 – 382 days in total: boys’ answers totalled 139, girls’ 243
Question 5 – 379 days in total: boys’ answers totalled 139, girls’ 240
Question 6 – 377 days in total: boys’ answers totalled 136, girls’ 241

Table 6.6 Screen-based behaviour according to the multiple choice questions 1 to 4.

	Answers to multiple-choice questions		
	Number of children/72 (%)	**Average per week (SD)**	**Total number of days (%)**
Question 1: How much time did you spend watching TV outside of school today?			
I didn't watch TV at all	46 (63.8)	2.7 (1.8)	125 (32.6)
I watched less than one hour today	57 (79.1)	2.2 (1.2)	127 (33.2)
I watched one to two hours today	48 (66.6)	1.7 (0.9)	81 (21.1)
I watched two to three hours today	10 (13.8)	1.8 (1.0)	18 (4.7)
I watched more than three hours today	17 (23.6)	1.9 (1.3)	32 (8.4)
Question 2: How much time did you spend playing video games outside of school today?			
I didn't really play at all	59 (81.9)	3.3 (1.9)	196 (51.3)
I played less than one hour today	44 (61.1)	2.0 (1.3)	89 (23.3)
I played one to two hours today	40 (55.5)	1.5 (0.8)	59 (15.4)
I played two to three hours today	10 (13.8)	1.5 (0.7)	15 (3.9)
I played more than three hours today	11 (15.2)	2.1 (1.4)	23 (6)
Question 3: How much time did you spend using a computer outside of school today?			
I didn't really use a computer at all	64 (88.8)	3.8 (1.6)	244 (63.9)
I used a computer less than one hour today	41 (56.9)	2.0 (1.2)	82 (21.5)
I used a computer one to two hours today	23 (31.9)	1.3 (0.6)	31 (8.1)
I used a computer two to three hours today	7 (9.7)	1.1 (0.4)	8 (2)
I used a computer more than three hours today	9 (12.5)	1.8 (1.4)	17 (4.5)
Question 4: How much time did you spend using a mobile phone today?			
I didn't really use a mobile phone	61 (84.7)	3.9 (2.1)	242 (63.4)
I used a phone less than one hour today	34 (47.2)	2.0 (1.4)	74 (19.4)
I used a phone one to two hours today	15 (20.8)	1.4 (0.6)	21 (5.5)
I used a phone two to three hours today	14 (19.4)	1.6 (1.3)	23 (6)
I used a phone more than three hours today	10 (13.8)	2.2 (1.9)	22 (5.7)

Participants took 300 photos during the study. 142 of the photos had written text attached, while 37 had voice recordings, explaining what the photo was about. Despite being instructed not to take photos of people, 29 photos had to be subsequently "blurred", as faces were recognisable. However, 10 of these were useable within the analysis as their comments explained the context of the photo, resulting in 281 photos used in the analysis. On average, participants took photos on 4 of the 7 data collection days. Even though the question clearly asked to take a photo of an activity they did while *sitting* or *lying down*, participants often chose to take photos of any activity they did during the day, not only sedentary activities. However, the majority of photos (68%) were taken of various sedentary activities, with screen time the most frequently photographed behaviour. A total of 110 photos (39%) were taken of different screens including televisions (35 photos by 14 girls and 8 boys), video game consoles like an Xbox or PlayStation (27 photos by 6 girls and 9 boys), tablets (21 photos by 7 girls and 3 boys), computers / laptops (13 photos by 6 girls and 1 boy) and mobile phones (12 photos by 11 girls). Often the voice recordings or written text attached to the photos provided more detail, like a photo of a TV screen with the following attached: "While eating my breakfast I watched YouTube" (P28).

Other types of SBs photographed include playing with toys (24 photos by 11 girls and 4 boys), reading books (17 photos by 7 girls and 8 boys), followed by 13 photos from 8 girls and 2 boys of a bed/couch, arts and crafts (13 photos by 9 girls and 1 boy) and homework (9 photos from 6 girls). As stated earlier, sometimes children reported other, non-sedentary types of behaviours. Most notably were 19 photos (by 5 girls and 5 boys) related to physical activities they participated in during that day, e.g. swimwear, a bicycle, a park or a garden with a football.

From the "Draw a picture" tool, 333 drawings were downloaded, with written text attached to 174 and voice recordings attached to 24 drawings. Twenty-five of the drawing files were blank, leaving 308 drawings for analysis. As with the photos, participants often chose to ignore the question and drew any activity they took part in, including 40 drawings (by 7 girls and 6 boys) related to physical activity. Again, screen time was the most reported sedentary activity, with 114 (37%) drawings depicting screen-based behaviours. These included 43 drawings of television viewing (by 17 girls and 7 boys), 27 drawings of playing video games (by 3 girls and 9 boys), 17 drawings of spending time on a mobile phone (by 7 girls and 2 boys), 14 drawings of playing with a tablet (by 6 girls and 2 boys) and 13 drawings of a computer/laptop (by 7 girls and 1 boy). Other after-school sedentary activities included reading (10 by 8 girls and 1 boy), playing with toys (11 by 6 girls and 2 boys), arts & crafts (11 by 8 girls and 1 boy), spending time on the bed/couch (6 by 6 girls), playing a musical instrument (4 by 4 girls), sitting in the car (3 by 2 girls and 1 boy) or church (3 by 2 girls and 1 boy) and homework (3 by 2 girls and 1 boy). Figure 6.2 shows some examples from the “Take a photo” and “Draw a picture” tools.

The “Record your voice” tool yielded 550 recordings, made over a total of 278 days. Thirteen files were blank and one corrupted, leaving 536 recordings used in the analysis. This was the least preferred method for the participants to use, recording their voices on average 3.79 (SD=2.45) days per week. As with the other data collection tools, screen time was the most frequently reported activity, with participants mentioning it 154 times. While these were mainly reported in the afternoon (92 instances), except for one incidence of homework, screen time was also the only sedentary activity mentioned on weekday mornings (66 instances). Children reported watching television a total of 68 times, while other forms of screen time (video games (29), computer / laptop (29), tablet (21) and mobile phone (7)) were mentioned 86 times. As with the photos and drawings, girls reported these activities more often than boys, except for playing video games, which was mentioned 29 times by 12 boys and only 3 girls.

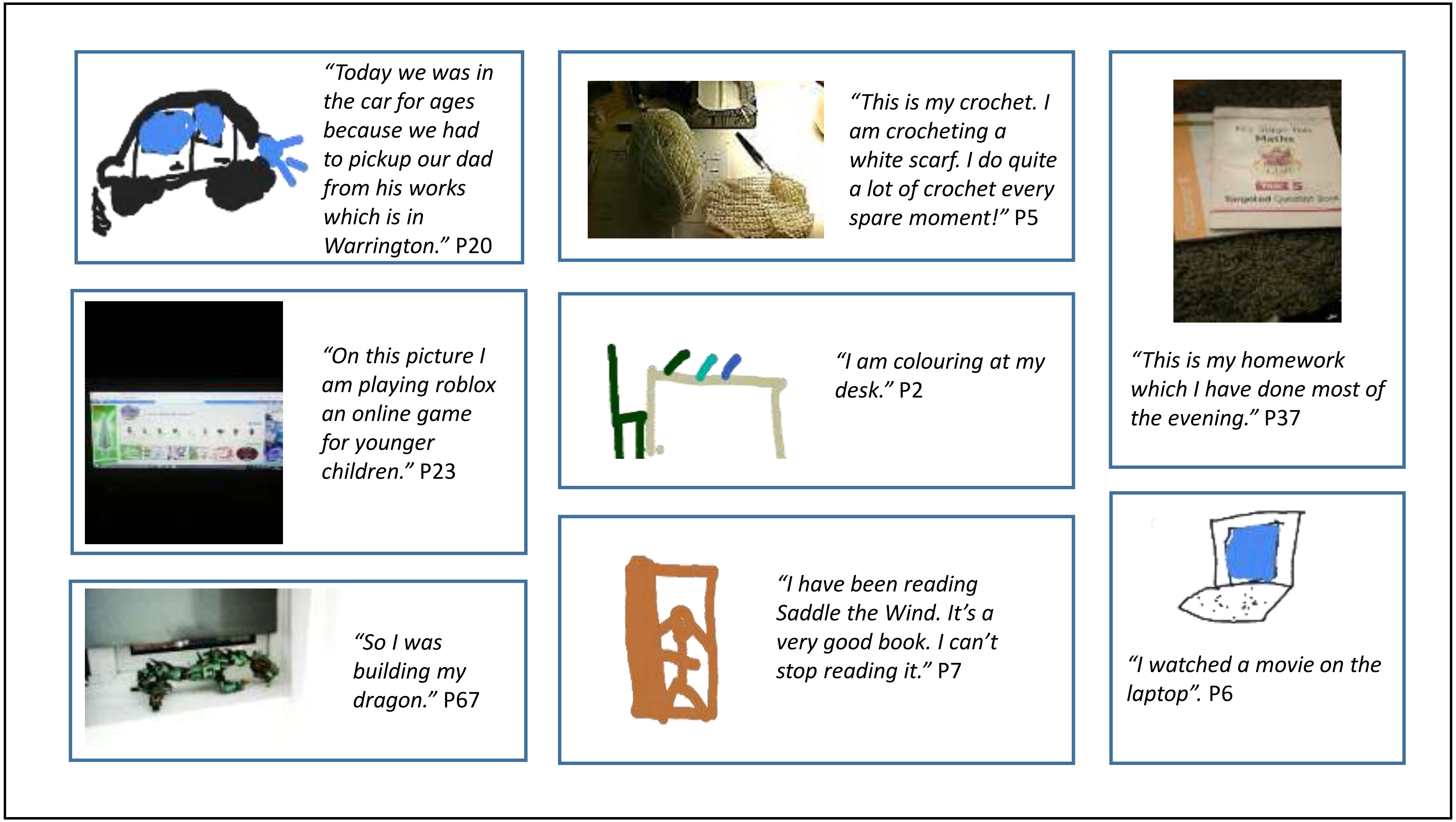


Figure 6.2 Examples of photos taken and drawings made by participants

The question "Can you tell us what you did this morning?", as expected, produced little variety during weekdays, with participants talking about their morning routines which typically included getting up, having breakfast, getting dressed and ready for school, brushing their teeth and going to school. Thirteen participants reported screen time on weekday mornings, with two of them mentioning it on all 5 weekday mornings and one on 4 weekday mornings. For these participants, the screen time seemed part of their morning routines. For example: *"This morning I had breakfast while on my laptop, got changed while on the laptop. Then I got off the laptop to brush my teeth…."* (P59). The "Record your voice" tool often provided the researchers with rich, contextual information. A discrete case study demonstrating this type of data from the app, adding context to sedentary time according to the accelerometer, is presented in Box 6.1.

Box 6.1: Case study of participant 7 (girl, P7)

On a Saturday evening at 20:12, P7 answered the question "Can you tell us what you did this afternoon?" with the following voice recording: *"When I came back from ballet, I played Minecraft. Then [Participant 4] came to visit. We played IQ puzzler, Dobble and I showed her my ballet. Then when she went home I played on my computer for a little while, bathed, ate dinner and played Minecraft a little. Then brushed my teeth and went to bed."* In this one recording, there is evidence of physical activity (ballet), video games (Minecraft), games/toys (IQ puzzler and Dobble) and computer time all within one afternoon. Accelerometer data revealed that despite an hour's ballet lesson, P7 only engaged in 50 minutes of MVPA that day, while 652 min was spent sedentary. Not all children, however, gave such detailed accounts of their day. Participant 4's voice recording from the same afternoon simply stated: *"I went to [P7's] house"*.

Most participants reported their sedentary activities without hesitation or any evidence of social desirability. For example P41's recording: "I came home from school and I went straight onto my iPad. After that I ate dinner. After that I went back to my iPad for a couple of hours." However, voice recordings from four participants revealed that they seemed aware of the fact that spending too much time in SBs might be frowned upon. For example these quotes from

P7: "…then I watched a little, little, *little*, bit of TV" and P24: "…got my iPAD and I played Roblox [an online game] for at least 2 hours or so, because I don't want to play on it too much".

The combination of accelerometer data, log sheets as well as the different data capturing tools via the app allowed for data triangulation, resulting in a comprehensive picture of the participants' behaviour across the whole week. Following are two case studies (presented in Boxes 6.2 and 6.3), chosen to show how the app sometimes provided clarity around 'irregular' accelerometer data.

Box 6.2: Case study of participant 32 (boy, P32)

Accelerometer data showed high levels of sedentary time on most weekdays (around 720 min, or 12 hours per day) and even higher on weekend days (818 min, or 13.6 hours per day). Data from the app revealed that he spent almost all of his free time playing video games, with 6 photos of his laptop, accompanied by written descriptions of the games he played as well as one photo of a games console.

Monday

Tuesday
"Today I was playing games on my laptop"

Wednesday

Thursday
"I was playing a game called Paladins"

Friday
"I'm now going to play a PHD"

Saturday

Sunday

He also drew 5 pictures of himself sitting in front of his laptop and all 14 voice recordings were about his games, for example *"This afternoon I was also playing games, which means I'm a gamer"* and *"This afternoon I was also playing games, you know, I am always playing games."* Despite this, he still managed to meet the recommended guidelines for physical activity (60 minutes of MVPA per day) on all 4 weekdays included in the analysis (mean of 72.2 minutes per day), but his MVPA levels dropped significantly over the weekend (mean of only 16 minutes per day). On Friday, however, his sedentary time dropped to 467 min (7.7 hours) per day, with 82.75 minutes of MVPA according to the accelerometer. That evening he drew a picture of four stick men and a bicycle lying next to them and wrote: *"I was going with my friends outside and I had a great time!"*

Monday

Tuesday

Wednesday

Thursday

Friday
"I was going with my friends outside and I had a great time!"

Sunday

As he meets the recommended guidelines for physical activity, without the contextual data from the app, we would not have understood how much time he spent in screen-based sedentary pursuits. In this case, intervention design should focus on replacing some of his video gaming time with more opportunities to play outside with friends.

Box 6.3: Case study of participant 2 (girl, P2)

On most days, P2 exceeded the government guidelines for physical activity with a mean MVPA of 70 minutes/day, except for Wednesday and Thursday when her activity levels dropped to 30 minutes of MVPA per day, together with an increase in sedentary time. On Wednesday she drew a picture of herself in bed and wrote *"I was lying in my bed"*. On Thursday she took a photo of her bed, drew a picture of herself in front of the television and wrote *"I was watching the TV at my Nanna's house"*.

Wednesday
"I am lying in my bed"

Thursday
"I was in my bed"

Thursday
"I was watching theTV at my nanna's house"

Voice recordings revealed how she started feeling ill on Wednesday morning *("…felt a little bit achy…"*) before going to school. Wednesday evening she reported how she felt worse: *"This afternoon I got home from school and I got my pyjamas on because I was feeling a lot achy…"* On Thursday, she reported that they dropped her siblings off at school after which she went home and watched television. In the afternoon, she went to her Nanna's and watched television until her mum came to pick her up. Without the context from these photos, drawings and recordings, data from the accelerometer alone would have led the researcher to identify P2 as a child not meeting the recommended government guidelines for physical activity (as on two days her MVPA fell well below the recommended 60 minutes per day). When we exclude the two days she was ill, her mean MVPA level was 70 minutes per day and her sedentary time only 542 min per day (i.e. 87 minutes less than the group mean). Thus, contextual data from the app allowed the researcher to classify her as a typically sufficiently active child spending much less time than her peers in sedentary pursuits.

6.4 Discussion

The aim of the study was to explore whether a digitalised data capture tool in combination with accelerometry could capture SB more comprehensively, by adding contextual data to ST derived according to accelerometers. Results indicate that this method *can* be used to assess children's SBs, as data triangulation of the photos, drawings and voice recordings derived from the app and added to accelerometer data, resulted in a representative picture of participants' behaviour.

Accelerometer wear compliance was high and all the participants used the DCDC app during the 7 days of data collection. While most participants complied with the task of opening the app daily and answering the questions, they sometimes gave unrelated answers. The questions on the app asked about sedentary activities only (except for the "Record your voice" tool), but children often chose to ignore the question and responded with an unrelated answer. However, most often these answers were related to physical activity and whilst that was not the main purpose, it still provided the researcher with contextual information about the 24-hour movement profile and highlights the potential of the app to be used in future studies to add context to both physical activity and SB. The "Record your voice" tool allowed for easy detection of social desirability or the awareness of excessive screen time, and as this was only evident in four participants' recordings, the researcher is confident that most participants reported their screen-based behaviours honestly and accurately.

Results from this study showed that on average, the participants spent more than 10 hours per day (629 min) in sedentary pursuits. This result, however, is according to an intensity threshold (50 m*g*) unable to distinguish between postures. Therefore, it is likely to overestimate sedentary time by about 5% (see results from Study 2) as it will likely include time spent standing still. It has recently been suggested that the term *stationary time* is more accurate when describing time spent below this threshold (Freedson, 2018). The reported 48% of time spent in seated / lying postures according to the Sedentary Sphere analysis should be considered with caution, as the method tends to underestimate free-living sitting time in children by about 10% (see results from Study 2).

According to data from the app, most of the participants' out of school SB was spent using a variety of screens. The observed increases in TV viewing and video gaming over weekends could explain the increased amount of ST observed in the accelerometer data during this period. On weekend days, the participants engaged in these behaviours long enough to exceed the equivalent time spent sitting in school on weekdays. Participants' increased ST and decreased MVPA observed over weekends is consistent with findings from previous studies (Steele et al., 2010; Brooke et al., 2014). Whilst boys engaged in significantly higher levels of MVPA compared to girls (also consistent with previous literature (Hallal et al., 2012)), there were no significant differences found in their STs. The steeper intensity gradient observed in girls indicates that they have a poorer intensity profile, with less time spent across the intensity range compared with boys. A recent study showed that a higher (shallower) intensity profile, as observed in the boys, is associated with favourable changes in health indicators (Fairclough et al., 2019b).

Data from the DCDC app added context to the accelerometry results, illustrating various forms of screen time as the main behaviour reported across all four data capturing tools. These include TV viewing, video game consoles, tablets, computers / laptops and mobile phones. Results from the multiple choice questionnaire revealed that on 64% of days, the participants reported not using a computer at all, suggesting that for participants within this age group, SB does not comprise of much computer time. From the amount of days children reported not using a mobile phone at all (63%), it can perhaps be assumed that most participants did not yet own their own mobile phones. However, 45 (62.5%) participants reported that on at least one day they had used a mobile phone. It is unknown whether they used their own, or parent's / carer's / other adult's phone.

Photos, drawings and voice recordings revealed that, for these participants, TV viewing was not children's main screen-based activity. Watching YouTube videos, playing online games like Roblox or Fortnite, watching movies (on tablets or laptops) and talking with friends (online via social media) were activities most frequently reported by participants. This trend, showing a decreased amount of TV viewing with increasingly higher usage of other screen-based devices is consistent with results from a recent review of studies (Schaan et al., 2019). Across all photos, drawings and voice recordings, girls reported using these devices more frequently than boys, except for playing video games, suggesting that for boys video gaming was their preferred screen-based activity. A recent study by Perrino et al. (2019) confirms this gender-based difference, with girls engaged in types of screen time more likely to involve social contact and communication. This is an important finding, suggesting that interventions aiming to reduce screen use should be targeted differently for boys and girls. Furthermore, Suchert et al. (2015) found that screen-based SBs had different associations with mental health indicators in boys versus girls. For example, higher screen-based SBs were associated with lower self-esteem in girls, but higher self-esteem in boys. This finding is likely the result of boys mainly playing video games (as observed in the present study), during which they master new challenges accompanied by a sense of achievement, while girls spend time on social media, often comparing themselves to unrealistic images of female body ideals (Suchert et al., 2015).

Interventions designed to reduce some of the time boys spend playing video games, should aim to replace the behaviour with PAs that might have a similar outcome (e.g. an obstacle course that increases in levels of difficulty). Girls, on the other hand, might benefit from PA interventions that allow them to socialise with their friends, therefore replacing their time spent on social media by spending time with peers in real life, who are less likely to portray unrealistic body ideals.

Playing with toys, reading, arts and crafts and homework were the only other sedentary activities reported across all data capturing tools. However, these behaviours would probably not be targeted during interventions aiming to reduce SB, due to their positive association with academic achievement (Carson et al., 2016a). While summarising the results from the app on group level proved to be difficult, the main strength of the method lies on the individual level. Despite not having full compliance by way of full datasets, most participants still provided the researchers with contextual data beyond what the accelerometer alone can offer. The app allowed participants to choose their preferred method of reporting their behaviour. While some children mainly took photos, others chose to draw pictures or record their voices. The app often complemented the objective data, by helping to explain the patterns of SB and PA observed.

One of the strengths of the app is that children only have to recall their behaviour from that specific day, which should minimise recall errors. Self-report use-of-time tools like MARCA or PDPAR (Foley et al., 2012) have successfully been used to report *previous* day behaviours of children, however, most focus on PA with limited information gathered regarding SB. Children might be able to choose from a selection of screen time activities (TV, video games, computer use etc.), but with the fast-paced technological advances and children's increased access to screen-based devices, more details are required. For example, data from the app showed the current popularity of watching YouTube videos and playing Fortnite, which provides useful information when attempting to understand children's SBs and when designing interventions targeting reductions in SB.

Another strength of the app was that the four tools complemented each other. For example, sometimes a photo in itself was not clear, but the recordings clarified it or the other way around. Using only one or two of the four tools would not have given the same amount of depth and would most likely have resulted in unclear photos or drawings being discarded. This type of data triangulation, together with the assessment of sedentary time using accelerometers is effective in more comprehensively describing individual children's physical behaviour over the seven days of data collection. This, however, is only possible in cases where the child complies with the task. For example, P4's account of her afternoon (*"I went to [P7's] house"*) is far less comprehensive than P7's description of the same period, highlighting the individual variation in reporting.

The method also has other limitations that require consideration. Typically, the researchers were given between 40 and 60 minutes with the participants, to complete anthropometric measurements, fit and explain accelerometers as well as familiarise the participants with the app. Classrooms were busy, with both participants and non-participants in attendance. This limited the time available for children to be familiarised with the app and to ask questions. Some data collection sessions took place close to Christmas, which resulted in a lot of photos, drawings and voice recordings about things like Christmas trees and festive activities. Though participants were engaging with the tool, this generated a considerable amount of irrelevant data. Future studies may wish to develop an online video explaining the tool and study that could also be shown in class detailing the necessary information. We also recommend that in future, software developers consider adding an interactive feature to the app, making it possible for the researcher to communicate with participants (via the app) during the data collection period, specifically in cases where a participant is not complying with the task. However, for the researcher to monitor incoming results from the Tablet Application to the Supporting Server Application, an internet connection would be needed and there are a number of ethical considerations to take into account. While this method should reduce recall errors, some degree of recall is still required, and especially the question regarding their time spent in the mornings before school, might have been affected by recall errors. Finally, the aim of the study was not to specifically assess the validity of the app or sections of the app for measuring SB, however, future studies may investigate this.

6.5 Conclusions

This study combined accelerometry with a mixed-method digitalised self-report data capturing tool (app), and captured children's SBs comprehensively. Various forms of screen time were identified as activities that need to be targeted in future interventions, with a distinct difference observed between boys' and girls' preferences. Results from this study suggest that gender-specific interventions are needed when aiming to reduce children's SB. On an individual level, the app added context to accelerometer data, often explaining irregular PA and SB patterns. It might be used in studies prior to intervention, in order to identify specific behaviours to be targeted or during evaluation to observe any changes in reported behaviours. The app can potentially be used in future studies to add rich, contextual information about the whole 24-hour movement continuum, that has been absent in the literature until now.

Thesis study map

Study	Aims and key findings
Study 1: Establishing raw acceleration thresholds to classify sedentary and stationary behaviours in children	**Aims:** 1. To compare the raw accelerometer output of ActiGraph (AG) and GENEActiv (GA) accelerometers across different placements, 2. To identify raw acceleration signal thresholds for different sedentary behaviours in children, from both the hip and wrist, using AG and GA, 3. To validate the thresholds during free-living activities. **Key findings:** • Hip worn AG monitors resulted in significantly lower acceleration output compared to wrist worn monitors, and are not comparable. • Statistically significant differences between accelerometer outputs of sedentary activities were observed, however these differences are unlikely to be meaningful in practice. • Inconsistent differences between GA and AG monitors were observed during calibration, however free-living data confirmed that the differences were small and unlikely to be meaningful in practice. • Sedentary and stationary thresholds were developed for AG hip, AG and GA non-dominant and dominant wrist placements. • The sedentary thresholds slightly overestimated free-living sedentary time compared with activPAL. The stationary thresholds underestimated stationary time according to activPAL.
Study 2: Validating the Sedentary Sphere method in children.	**Aims:** 1. To validate the Sedentary Sphere method of classifying posture, in child populations using GENEActiv and ActiGraph GT9X wrist-worn accelerometers

	Key findings: • During most observed activities posture classification was high (~78%), irrespective of brand or placement. • "Standing with phone" was misclassified most of the time. • Classification accuracy during free-living was consistent with observed activities (77%), but the method underestimated sitting time compared with activPAL.
Study 3: Exploring a novel mixed-methods approach to assess children's sedentary behaviours.	**Aims:** 1. To explore the efficacy of using accelerometry in combination with a digitalised data capture tool, the Digitising Children's Data Collection (DCDC) for Health, in order to capture children's SBs more comprehensively. **Key findings:** • The DCDC app can be used to add contextual data to accelerometer results, thus capturing SB comprehensively. • Participants spent 629 (SD = 51) minutes per day below the 50m*g* threshold. • DCDC app data revealed that most out-of-school free time was spent using a variety of screen-based devices. • ST according to accelerometry increased over weekends, while app data confirmed this with increased amounts of screen usage reported over weekends. • There was no statistically significant difference between girls' and boys' ST according to accelerometry. • App data revealed differences in screen-based behaviours, with boys preferring to play video games while girls spent time on mobile phones, laptops and tablets. • Playing with toys, arts and crafts, reading and homework were activities reported through all tools (photos, drawings and voice recordings). • On an individual level the app often explained irregular patterns of SB and PA observed through accelerometry.

Study 4: Parental perceptions of the factors influencing children's sedentary behaviours.	**Aims:** 1. To determine if parents' perceptions of the factors influencing children's SBs are the same as those identified by an expert scientist working group, 2. To identify any factors influencing children's SBs not listed by the expert scientist group, and 3. To acquire parents' input and recommendations for future interventions aiming to reduce children's SBs.

CHAPTER 7

STUDY 4

PARENTAL PERCEPTIONS OF THE FACTORS INFLUENCING CHILDREN'S SEDENTARY BEHAVIOURS

7.1 Introduction

SB research has received an increased amount of attention in recent years, prompting the Sedentary Behaviour Research Network to publish consensus definitions for terms related to SBs (Tremblay et al., 2017), as discussed in Chapter 2. Despite evidence that SB is related to adverse health outcomes (Saunders, Chaput and Tremblay, 2014), children today predominantly spend their waking hours engaged in sedentary pursuits (Carson et al., 2016b; Talarico and Janssen, 2018), with an increasingly higher prevalence of screen time reported worldwide (McMillan, McIsaac and Janssen, 2015; Mielgo-Ayuso et al., 2017; Pearson et al., 2017; Schaan et al., 2019). Salmon et al. (2011, p.204) termed the current era the "sedentary age".

In order to target SB effectively, researchers need an understanding of the multiple levels of factors that might influence the behaviour across different settings. Conceptual frameworks, models or theories can help explain and predict the behaviour, as well as provide guidance for intervention design (Hadgraft, Dunstan and Owen, 2018). While social-cognitive theories focus mainly on individual-level influences on behaviour (Hadgraft, Dunstan and Owen, 2018), Owen and colleagues proposed the use of an ecological model of SB, that emphasizes environmental, social and policy factors as important influencers on behaviour (Owen et al., 2011). Their framework has four domains (leisure, household, transport and occupation), each with a range of potential influencing factors. Applying ecological models to health research, however, can be challenging as it involves complex, multi-level studies (Hadgraft, Dunstan and Owen, 2018). Other limitations of ecological models include the fact that they rest on the assumption of hierarchical dependencies between spheres of influence (Chastin et al., 2016a) and do not specify the connections between the different levels of influences (Hadgraft, Dunstan and Owen, 2018).

Recently, a broad collaborative project attempted to address these limitations by developing an international transdisciplinary consensus framework, that of the Systems of Sedentary behaviours (SOS-framework) (Chastin et al., 2016a). The framework was developed by an international expert-scientist working group, for the study of determinants, research priorities and policy on SB across different age groups. The experts acknowledge the complexity of the behaviour, stating that SB is “influenced and conditioned by multiple inter-dependent factors acting on multiple levels” (Chastin et al., 2016a, p.2). Therefore, it is argued that a systems-based approach is more suitable for studying SB, as it focusses on the interrelationship of various parts (subsystems) and its functioning as a whole (a system), as opposed to the hierarchical structure of ecological models. Through a comprehensive concept mapping approach, the SOS-framework was developed and consists of six clusters of determinants. Each determinant has a list of influencing factors deemed to have the highest modifiability and population effect size. Figure 7.1 shows the six clusters of determinants in the SOS-framework. There is no hierarchy and no formal lines drawn between the clusters, as they are all inter-related and their web of factors interact synergistically to either promote or prevent SB (Chastin et al., 2016a).

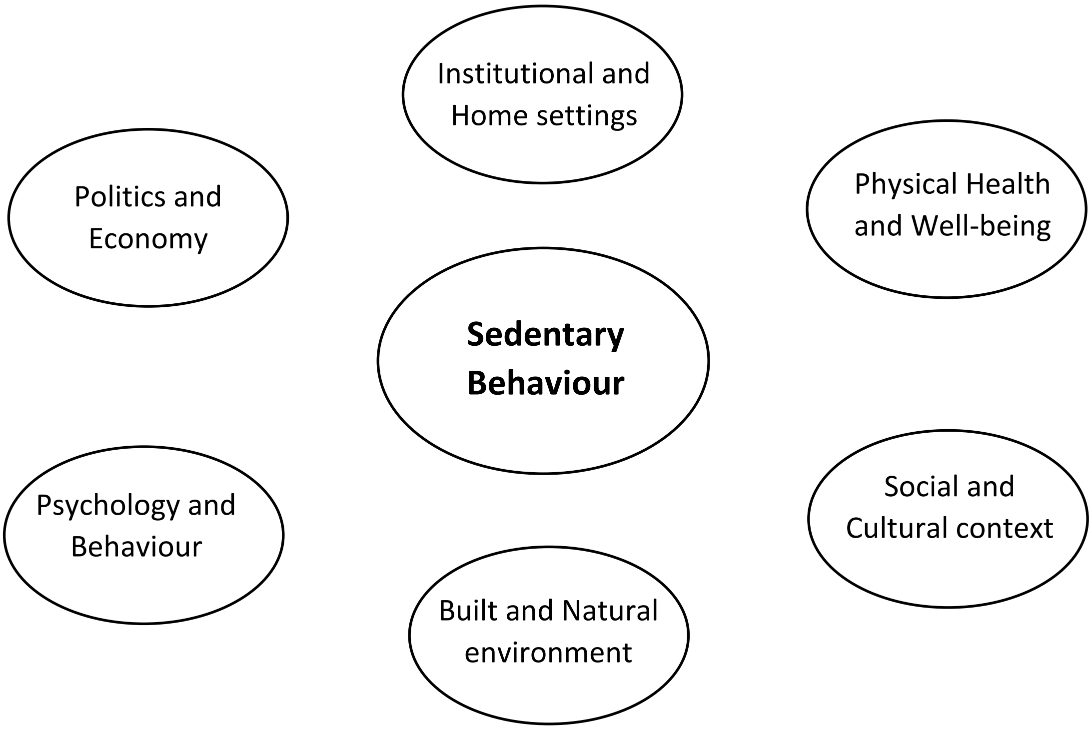


Figure 7.1 The SOS-framework (Chastin et al., 2016a)

The previous chapters of this thesis focused mainly on assessing children's ST or SB, using accelerometry (Chapters 4, 5, 6) and a self-report tool (Chapter 6). While Study 3 (Chapter 6) added important contextual information to accelerometer data, the question *why* children spend so much time sedentary remains unanswered. Before designing and planning interventions aimed to reduce SB, more information is needed regarding the determinants of the behaviour and the factors involved in influencing the behaviour. Parents play a key role in their children's screen-based behaviours, as they are the providers of screen-based devices, the rule-makers regarding screen time in the family setting and role models of the behaviour (Jago et al., 2010). Their views on children's SBs and their perceptions influencing these behaviours can provide researchers with valuable insights needed for intervention design.

To the best of my knowledge, no previous study focussing on parental views of children's SBs, has been underpinned by the SOS-framework. The present study therefore aimed to determine if parents concur with the expert group, specifically around factors they feel influence their children's SBs. A second aim was to identify any new factors, perceived by parents to influence their children's SBs, and thirdly to acquire parents' input and recommendations for future interventions aiming to reduce ST.

7.2 Methods

7.2.1 "E-interviews"

Previous research focussing on parents' perceptions of children's SB or screen-based behaviour have mainly used traditional face-to-face / telephone interviews (e.g. Knowles, Kirk and Hughes, 2015; Thompson et al., 2017; Jago et al., 2018) or focus groups (e.g. Carson et al., 2014) as methods for data collection. With the Internet becoming widely accessible over the last two decades, researchers from different fields of study have explored the use of email interviews, or "e-interviews" (Bampton and Cowton, 2002) as an alternative to the more traditional face-to-face interview (Gibson, 2010; Bowden and Galindo-Gonzalez, 2015; James, 2015).

One of the advantages of e-interviews is, unlike face-to-face interviews, the researcher and participants are not restricted to a specific time and space (Bampton and Cowton, 2002). Not only can participants choose to respond at a time they find most convenient, but it also allows the researcher time to reflect on any answers before typing the next question (Gibson, 2010). E-interviews do not have to be transcribed, giving the researcher more time for data collection and analysis, while also eliminating any transcription errors (Hamilton and Bowers, 2006). Recruiting parents can be challenging, as their free time is limited which can result in low response rates (e.g. 25%, Noonan et al., 2016a). Using the e-interview might overcome some of the traditional barriers to data collection with parents.

7.2.2 Recruitment and participants

Thirty-three parents were invited to participate in the study. All prospective participants were parents of child participants from Study 3 (Chapter 6), who had indicated on consent forms that they would be interested to receive information with regard to future studies. Parents were initially contacted by telephone, given a brief description of the study and asked if they were interested to be interviewed via email.

Twenty-two parents gave permission to receive emails with more information and provided their email addresses for doing so. The first email contained the study information as well as a link to a short online survey. The online survey (Appendix G) asked for the participants' consent to be interviewed via email as well as their descriptive and demographic characteristics e.g. education, ethnicity, number of children in the house. Fourteen parents completed the online survey and thus received a second email with the first five questions. The information sheet (attached to the first email, see Appendix F) as well as the second email contained the definition of SB, with some examples of children's typical SBs, in order to prepare participants for the questions that followed. Eight parents responded to the interview questions and received the next round of questions. Seven parents completed all four rounds of questions, while one stopped responding after the second round.

7.2.3 E-interview procedure

All emails were sent individually and contained 3-5 questions at a time as recommended by Gibson (2010). Interview questions were developed by the lead researcher and refined after input from the supervisory team (see Appendix H). Questions centred around three main topics: parents' awareness of their children's SBs (e.g. "What types of sedentary activities does your child take part in outside of school?", "Is your child's sedentary behaviour something that worries you and why or why not?"), factors influencing their children's SBs (e.g. "What factors do you feel compete with your chances to be more active as a family?") and their views regarding future interventions (e.g. "In an ideal world, what do you think needs to change for children to become more active and less sedentary?"). The first few questions regarding parents' awareness of their own children's SBs were asked not only to elicit their views, but also to stimulate thinking about their children's behaviours for the upcoming questions regarding influencing factors. During the third round of questions, participants were provided with the list of factors identified in each cluster of the SOS-framework as having the highest modifiability and population effect size scores for youths (Chastin et al., 2016b), and asked to highlight and then prioritise the factors they feel have an influence on their child's SBs.

7.2.4 Ethical considerations

Potential participants were recruited after gaining institutional ethical approval (Appendix I). One of the key concerns of online research methods is whether the data is in the public domain (Germain et al., 2018). Unlike methods that involve for example public online forums, the e-interview participants were informed that the email account they sent their responses to is a secure domain (see Participant Information sheet, Appendix F). However, they were warned that their own email account might not be a secure domain. Once received, the email threads were copied and pasted into a password protected Word document, after which the emails were permanently deleted. The Participant Information sheet provided the participants with contact details of the university's Data Protection Officer as well as details of the University's general data protection regulation (GDPR) policy.

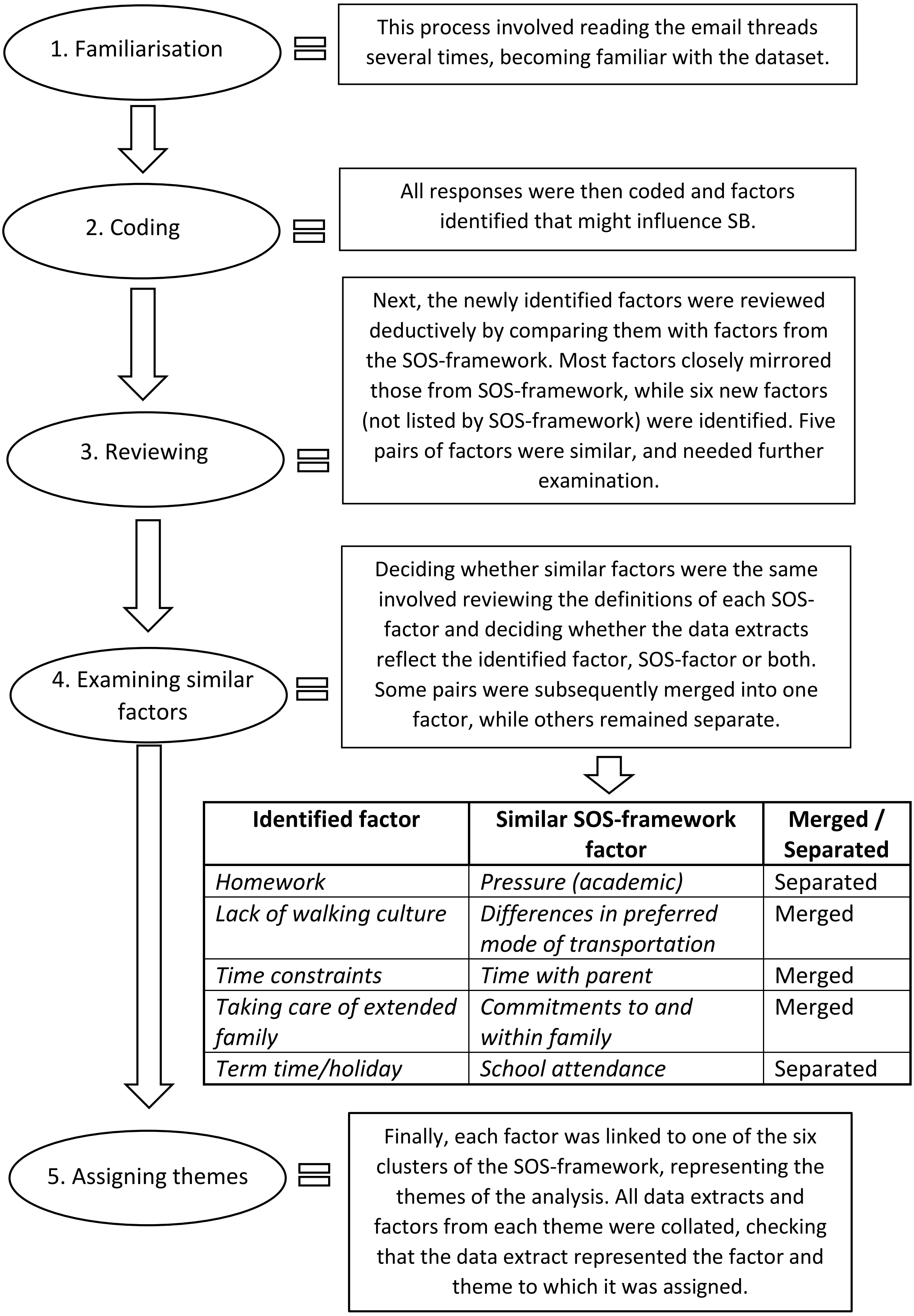
Researcher reflections on methods

The e-interview method appealed to me, because as a parent, I knew first-hand that my potential participants would likely have limited free time. Logistically I knew that finding mutually agreeable times for conducting interviews might prove to be difficult. I decided against conducting telephone interviews, as my South African accent in combination with the participants' Liverpool / Widnes accents might result in valuable information 'getting lost in translation'. As my eldest was also a participant in Study 3, I often felt that I could relate to answers given by my participants. My own, personal views and experiences are expressed in the first person in short, reflective stop-offs throughout this chapter.

7.3 Data analysis

The email threads formed the data for this study, and copied into a Word document, the data totalled 49 pages of double-spaced Arial font size 12. Most participants gave lengthy and detailed answers to questions, resulting in rich data for analysis. Two however, kept their answers very short. Word count of full interviews was on average 964 per interview (maximum 2169, minimum 153). Reflexive thematic analysis as described by Braun and Clarke (2006) and Clarke and Braun (2017) was used in a deductive way to analyse the data. Figure 7.2 illustrates the data analysis process. It involved five steps: 1) familiarisation with the data, 2) coding responses and identifying factors, 3) reviewing newly identified factors deductively by comparing them to SOS-framework factors, 4) examining similar factors and 5) assigning themes. During steps 1 and 2 (Figure 7.2) the list of factors provided by the SOS-framework (and the participants' answers to the direct question about those factors) were ignored, but the codes were subsequently reviewed (step 3) in a deductive manner, looking for similarities between codes and factors identified by the SOS-framework experts. Many factors were the same as those from the expert group, but six new factors were identified (step 3). Some factors were similar and further investigation (step 4) involved examining the published definitions of the SOS-framework factors (Chastin et al., 2016b) to decide whether the similar pairs were in fact the same or different. In some cases, the extracts represented both, and the initial coding underwent name changing to merge with the factor identified by the expert group (see inserted table in Figure 7.2). Two pairs, however, were separated, as the data extracts did not represent the expert group's definition of terms. For example "Pressure (academic)" is defined as *"the use of persuasion or intimidation to make someone do something they may or may not want to do"* (Chastin et al., 2016b). After reviewing the data extracts it became clear that the amount of homework that parents mentioned (identified factor: *homework*) were not the same as academic pressure, therefore the two were separated. The six clusters of the SOS-framework represents the themes of the analysis (step 5).

As the researcher is also a mother of one of the participants in Study 3, she was conscious that researcher bias was likely present. To enhance the trustworthiness of data collection and analysis, members of the supervisory team acted as 'critical friends' (Smith and McGannon, 2017), offering direction during formal and informal meetings and challenging assumptions made by the researcher. The six clusters / themes and their accompanying factors are discussed individually. Results from the other two topics covered by interview questions (i.e. parent's awareness of their children's SBs and recommendations for future interventions) are briefly summarised. Names of children in direct quotes have been changed to preserve confidentiality.



Identified factor	**Similar SOS-framework factor**	**Merged / Separated**
Homework	*Pressure (academic)*	Separated
Lack of walking culture	*Differences in preferred mode of transportation*	Merged
Time constraints	*Time with parent*	Merged
Taking care of extended family	*Commitments to and within family*	Merged
Term time/holiday	*School attendance*	Separated

Figure 7.2 Flow diagram of data analysis

7.4 Results

7.4.1 Describing the participants

All eight parents interviewed were female. Their individual descriptive and demographic characteristics obtained from the online survey, are presented in Table 7.1, together with their children's accelerometer data from Study 3. The participants' children's ST ranged from 8.5 to 12 hours per day, and only two participants met the recommended government physical activity guidelines of 60 minutes of MVPA per day.

Table 7.1 Descriptive and demographic characteristics of participants and their children's accelerometer data.

Participant	Parent of girl / boy in Study 3 (Study 3 Participant no)	Ethnic origin	Education	Area level deprivation: IMD decile score	Access to backyard / garden	Number of children in the house	Child's accelerometer data from Study 3	
							ST (mean min/day)	MVPA (mean min/day)
P1	Girl (P35)	White British	High school	9	Yes	1	561	67
P2	Girl (P6)	Black Caribbean	University	1	No	3	660	52
P3	Girl (P10)	White British	High school	1	Yes	1	629	39
P4	Girl (P5)	White British	University	1	Yes	3	511	62
P5	Girl (P1)	White British	University	10	Yes	2	599	45
P6	Boy (P32)	White (other)	University	3	Yes	2	704	56
P7	Girl (P8)	White British	University	1	Yes	4	648	30
P8	Girl (P27)	White British	College	1	Yes	3	774	28

IMD decile score = Index of multiple deprivation 2015 decile scores, ranging from 1 to 10, with 1 representing the most deprived and 10 the least deprived.

7.4.2 Parental awareness of children's sedentary behaviours

The first few interview questions centred around parents' awareness of their children's SBs. When asked what types of sedentary activities their children engage in, parents listed a variety of behaviours, like different screen based activities (TV viewing by 7 participants, mobile phone use (n=3), computer / laptop (n=3), video games (n=2), tablet use (n=1)), reading (n=6), homework (n=4), arts and crafts (n=4) etc.) All of the activities mentioned by parents were already reported in Study 3 (Chapter 6) by the children themselves. Regarding the risks involved in spending too much time sedentary, parents mostly cited weight gain (n=6) and declined mental wellbeing (e.g. depression, anxiety, n=4) as possible consequences. Three parents mentioned sleep issues, with two of them specifically referring to their own children's sleep patterns affected during increased amounts of ST. Six parents admitted that they were concerned about their children's SBs, with one clearly concerned: "*This is a huge concern to me as I watch my child slowly becoming a person that I do not recognise… My concern is that they are developing habits that will stay with them in their adult lives and will not be interested in the importance of physical activity and staying fit and healthy or even the importance of living a longer, healthy life"* [P2]. Another parent (P4) said that while she is not worried about her 10-year-old, she *is* concerned about her 14-year-old whose sedentary habits she has to monitor more closely.

7.4.3 Factors influencing sedentary behaviour

Throughout the email transcripts, several factors were identified that parents felt influenced their children's SBs, and these are discussed below under the six clusters (determinants) of the

SOS-framework. Each cluster has an accompanying figure (Figures 7.3 – 7.8) to show the factors identified by the SOS-framework associated with that cluster (Chastin et al., 2016b).

7.4.3.1 Physical Health and Well-being

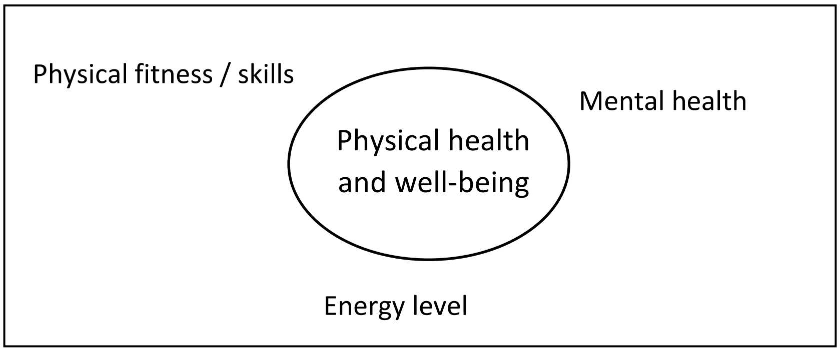


Figure 7.3: Physical Health and Well-being cluster and its influencing factors

The SOS-framework lists only three factors related to physical health and well-being (Figure 7.3). The "energy level of parent" was identified as a factor mentioned three times by one of the participants: *"Sometimes I am tired myself", "The factors that compete with our chances to be more active as a family are finances, time and energy, in that order"* and *"In order to keep them entertained requires my energy and time also"* [P2]. When presented with the SOS-framework list, three participants highlighted physical fitness / skills, three mentioned energy level and one mental health as factors influencing their children's behaviour. Two participants also put these in their list of top 5 factors affecting their children's SB: physical fitness/skill (P6), energy level (P6, P7) and mental health (P6). One participant has made physical activity a priority for her family after a health scare: *"My husband has recently undergone 2 major operations for slipped/collapsed discs and I am determined that as a family, we will become more active and healthy"* [P1]. No other factors related to this cluster were identified that were not already listed by the expert group.

7.4.3.2 Social and Cultural context

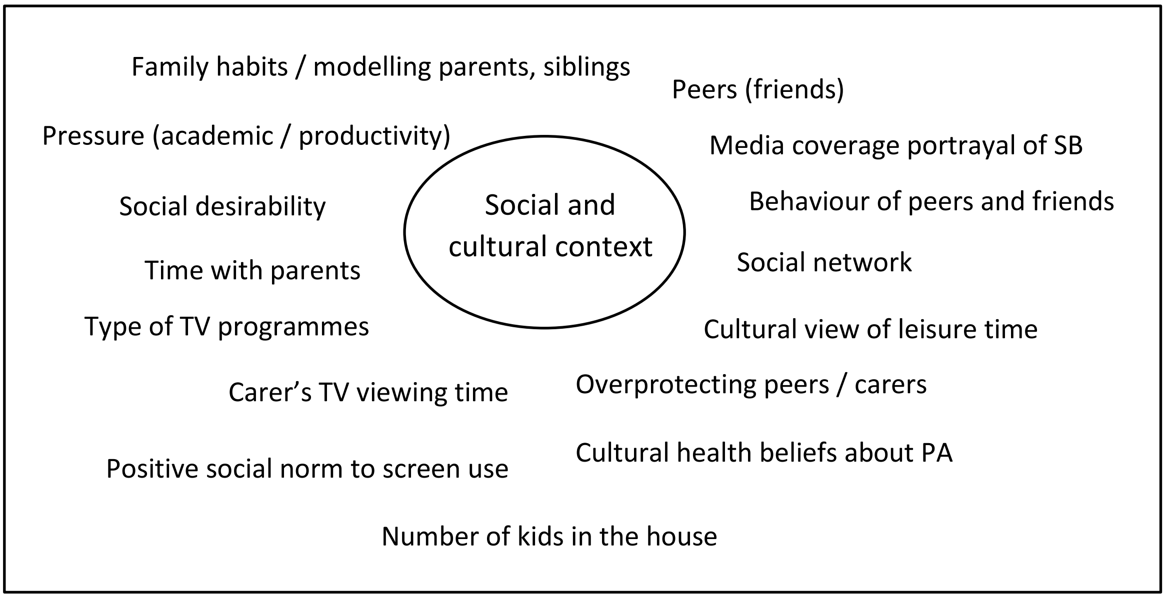


Figure 7.4: Social and Cultural context cluster and its influencing factors

There are 12 different factors related to the cluster *Social and cultural context* in the list provided by the expert group (Figure 7.4). Throughout the email threads, parents often cited time constraints as a factor preventing them from being more active as a family. In some cases, this was clearly due to the parent's work pressure or busy family life, e.g. *"Time! We are a busy working family. I leave the house before 6:30am each morning and we are all not back at home until 5:30pm at the earliest. By the time meals are cooked etc., running a house unfortunately takes over from getting out and being active together"* [P1].

Peers play an important role in determining SBs, sometimes increasing the behaviour for example *"Lizzy spends most screen time on her phone and we only gave in to get her one because all her friends had them"* [P1] and *"...social pressures for my daughter to be on social media like her friends"* [P3] (SOS-framework factor: Behaviour of peers and friends). On the other hand, peers can also help *reduce* sedentary activities, like this example from the family visiting Africa: *"At the moment in Kenya Jane is spending a lot less time in sedentary activities! She is able to be outside a lot more and has friends to play with"* [P5] (SOS-framework factor: Peers (friends)).

Family habits / modelling of parents or siblings is another factor mentioned by parents that can either increase or decrease sedentary activities, e.g. *"…adults also find it difficult not to be using technology all the time though and often set a bad example"* [P5] or *"We enjoy long walks, going to parks for picnics"* [P8]. The same goes for *number of kids in the house*, that can either decrease sedentary activities e.g. *"Because they have one another to play with, I think the screen is less of a pull"* [P7, who has four children], or sometimes act as a barrier to physical activity: *"The main competing factor* [preventing us from being more active as a family] *is the very heavy workload that my husband and I carry, related to having four children…"* [P7].

When presented with the list of factors, participants highlighted all the factors representing this cluster (Social and cultural settings) at least once, except for *media coverage portrayal of SB* and *cultural health beliefs about physical activity*. *Family habits* (P5), *peers* (P1, P3), *cultural view of leisure time* (P2), *social desirability* (P3), *number of kids in the house* (P3) and *time with parents* (6) were all listed in participants' top 5 factors influencing their children's SBs.

Three new factors were identified that are not listed by the expert group. The first is that *physical activity requires planning*, evident in these examples: *"Here in Kenya where we are for the summer, they play outside every day with local children. Being active seems to require more planning in the UK!"* [P5] and *"…so physical activity is limited to what we can structure into the routine as a family"* [P7]. In cases where increasing physical activity is not a priority, parents might not put in the effort to plan ahead. Another factor mentioned by two participants is the challenge of *finding activities enjoyable for the whole family*. For example: "*Finding things that we all enjoy doing together can be an issue too"* [P5] and *"it's hard finding something for all mixed age groups of my kids"* [P8]. *Homework* is the third new factor identified, with parents complaining that it takes too much of their children's after-school time, for example *"I really dislike the amount of time homework takes"* [P4] and calling for the abolishment of homework e.g. *"I think younger children should not be given homework, so that they have more time after school to play and do other activities"* [P5].

Researcher reflections on the Social and cultural context

In my own family life, we have had similar experiences. Peers and their behaviour have a strong influence on our daughter's behaviour. During her final year in primary school, she quit the school's cross-country club, only because her friend decided to stop running. No amount of encouragement could persuade her to continue. Since starting secondary school, she really enjoys her after-school dance club, but needs a lot of encouragement on days when her close friends are unable to go. Like P7, having four children in the house definitely helps us to be more active. When we go to the park as a family, there are enough of us to form two teams for a game of football or rounders, facilitating sufficient levels of MVPA for the whole family.

7.4.3.3 Built and Natural Environment

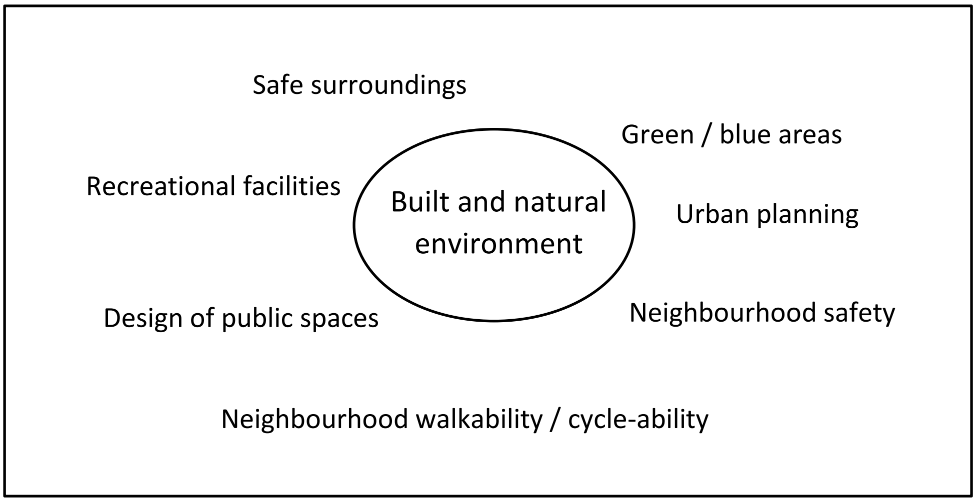


Figure 7.5: Built and Natural Environment cluster and its influencing factors

Figure 7.5 shows the seven factors concerning the built and natural environment listed by the expert group as having an influence on the SB of youths. Of all these factors, parents most frequently cited *neighbourhood safety* as a reason for their children not engaging in more PA. This is an example of the interrelationship between the different systems in the SOS-framework. Parents feel it is not safe for their children to play outside alone (neighbourhood safety/safe surroundings), but also feel they do not have the necessary time to go with them (Social and cultural context: time with parent), evident in this quote: *"I would say the main obstacle is our area… I feel leaving the girls outside unprotected is too risky. Likewise, the local park has always had a reputation. I would definitely not allow the girls to go to the park alone. The knock on effect is that I then have to have the time to accompany them"* [P4].

The lack of neighbourhood cycle-ability was mentioned by two parents, who both felt that cycling with younger children in Liverpool is not an option, due to the heavy traffic and lack of safe cycling lanes. Again, this links to a factor in the social and cultural context cluster, that physical activity requires planning and effort from parents. One parent talked about how they enjoy cycling as a family, but had to buy a bike rack in order to drive to areas that are safe for cycling. *"We found the Transpennine Trail* [a national coast-to-coast route for walkers, cyclists and horse riding] *this last week but you still have to drive to get to areas where you can cycle safely… cycling in the city with younger children is a headache… We have bought a bike rack…"* [P4]. All seven factors were highlighted by parents when presented with the list from experts, or identified by the researcher through other interview answers.

Neighbourhood safety (P5) and walkability/cycle-ability (P3) both featured in parents' list of the top 5 factors influencing their children's SBs. These two factors are closely linked: higher neighbourhood walkability (thus, more people walking daily) might lead to safer neighbourhoods, as noted by one parent who compared her experience in the UK with time spent in Uganda. *"…you would get to know one another better and look out for each other's children. In the community* [Uganda], *lots of people walk on the same routes each day and people know each other"* [P5]. No new factors were identified for this cluster.

7.4.3.4 Psychology and Behaviour

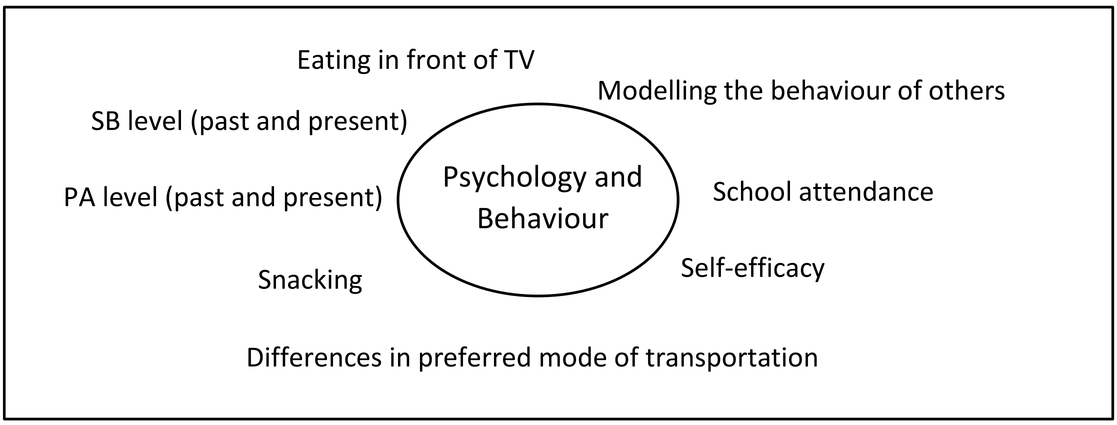


Figure 7.6 Psychology and Behaviour cluster and its influencing factors

There are eight different factors listed by the SOS-framework expert group related to psychology and behaviour (Figure 7.6). Differences in preferred mode of transportation was a factor mentioned by P2 more than once, e.g. *"I have tried to encourage my children to walk to school but there is such a strong protest as to why we can't just use the car. Unfortunately some parents see it as punishment allowing their children to walk anywhere. I get this a lot from my husband!"* Parents highlighted all the factors in this cluster when presented with the list from the expert group, except for *self-efficacy*. *School attendance* (P6, P7) and *modelling the behaviour of others* (P1) made it to the top 5 factors listed by parents.

When asked how much time they think their children spend in sedentary activities, three parents said that during holidays their children spend less time sedentary compared to term time, resulting in a new factor identified, named "term time/holiday". Another new factor identified for this cluster was "motivation". Two parents felt that their children lack motivation to engage in physical activity, thus increasing their ST. "*A disinterest* [in physical activity] *just seems to hover over and I have the uphill task of trying to motivate them to do anything worthwhile"* [P2]. Here she was specifically referring to the effects of spending too much time in front of screens, causing her child to become disinterested in other activities. Another example is this quote, from P7: "*She does not naturally decide to take physical exercise, although she will do so, and enjoy it, if encouraged."* Talking about house rules regarding screen time, P2 wrote this: "*In the holidays the only rule is that they have their shower first and breakfast and complete any chores before the TV. The incentive of being allowed to watch TV is what motivates them to carry out these instructions."* While the expert group did not identify *motivation* as a factor influencing the SBs of youths, they did include a factor named *psychology (attitude/temperament/motivation)* in their list pertaining to older adults.

7.4.3.5 Politics and Economy

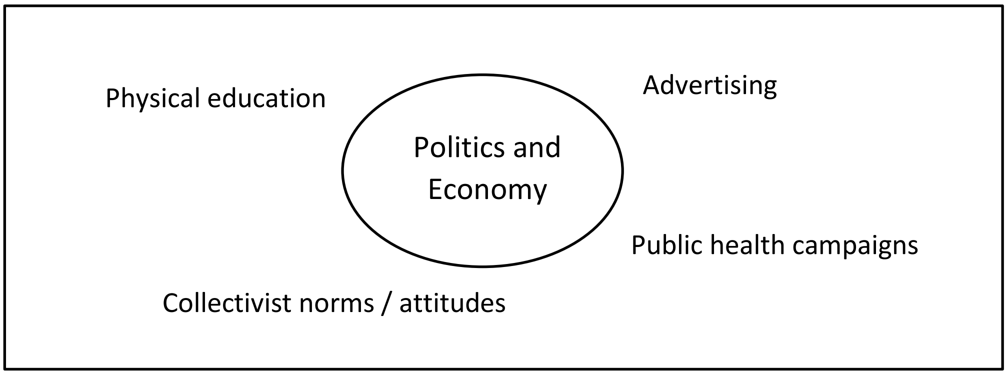


Figure 7.7 Policy and Economy cluster and its influencing factors

Figure 7.7 shows the four factors identified by the expert group and listed under the cluster labelled Politics and economy. During the interview questions, two participants mentioned physical education as a factor that could decrease SB. Only one participant (P2) highlighted factors in this cluster (advertising and collectivist norms/attitudes) when presented with the list from the expert group.

One added factor repeatedly pointed out by participants was financial restraints. The cost attached to many activities is viewed as a barrier to becoming more active as a family, resulting in everyone staying home and engaging in sedentary activities. Examples of quotes include: "*I think financial restraints are a massive issue, most safe out of school activities have a cost attached."* [P3], "*There is also a cost element too especially with the recent changes to swimming pool charges for example"* [P4]. Again this links to parents being the gatekeepers for children to become more active (and less sedentary), with some going to great lengths to achieve this, as the following quote illustrates:

"*As the summer holidays have now started I have arranged for my children to be in a multi sports camp. It costs £35 per child so I will spend £70 for my two, then there is the cost of food. Fortunately the camp is round the corner from our home so there is no travel expense. It is either that or they stay home all day every day and watch TV with the occasional trip out. They won't be able to do this for the whole of the summer holidays as it will be too expensive to keep up. I have taken on extra work through the summer holidays to do this"* [P2].

7.4.3.6 Institutional and Home settings

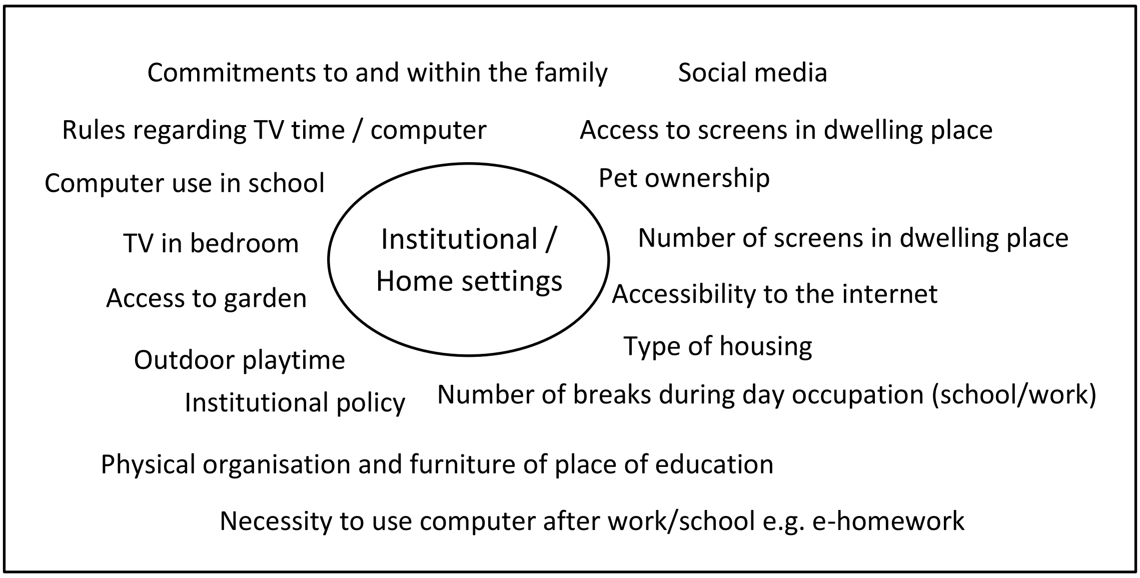


Figure 7.8 Institutional and Home settings cluster and its influencing factors

The expert group identified institutional and home settings as the most important cluster for researchers to investigate at present. Sixteen factors related to this cluster were identified (Figure 7.8). Five parents said that they have specific rules in their family regarding screen time, with three admitting that the rules they set are difficult to enforce and not always adhered to, like this quote suggests: "*They are never allowed to watch TV first thing in the morning on a school day or otherwise. This is the only rule that I have been able to maintain"* [P2].

The two factors most often identified from interview answers are *access to screen based devices* and *outdoor playtime*. *Access to screen based devices* seems to have a strong influence on SB of children in this age group: *"My phone is a constant battle as each time I put it down they pick it up"* [P2] and *"Mine* [phone] *is unlocked with my fingerprint because they were always trying to look over my shoulder to get my password!"* [P5]. While parents are the providers of different kinds of screen based devices, they might end up struggling to control its usage: *"I am always competing with screen time to gain my child's attention. We have Netflix, YouTube, PlayStation, Kindle, Laptops, mobile phones of which are all very appealing to a child's attention, we even have a TV screen in the car!"* [P2]. *Outdoor playtime* was never chosen by the participants when presented with the list of factors from the expert group, however, it was identified through other interview answers. For example: *"our children tend to be indoors a lot more and it is not easy to be as active indoors. Here in Kenya where we are for the summer, they play outside every day with local children"* [P5].

The following factors were all ranked within their top 5 by participants: computer use in school (P3), accessibility to the internet (P2), access to screen based devices (P1, P2, P5), number of screens in dwelling place (P2), access to garden (P1, P5), necessity to use computer after school (P2) and social media (P1). All other factors were highlighted by the participants except for *physical organisation and furniture of place of education*, *TV in bedroom*, *number of breaks during day (school/work)* and *institutional policy*.

Researcher reflections on Institutional and home settings

Access to screen based devices plays a noteworthy part in our children's SBs. We gave our daughter her first mobile phone during her last year of primary school and observed a significant change in her behaviour, despite strictly monitoring her screen time. We do not own a TV, but all our children have their own laptops. As parents, my husband and I found that our house rules regarding screen time has to evolve constantly, as the children's screen habits change. I found it interesting that parents are unable to adhere to the rules they themselves have set for their children. Perhaps this is due to my husband and I both growing up in a more traditional (South African) society where children do what their parents command or face the consequences. In addition, we strictly enforce our family rules and routines, because with four children in the house, the alternative might result in too much chaos.

7.4.4 Recommendations for future interventions

When asked what the participants felt needs to change for children to become more active and less sedentary, most parents (P2, P3, P4, P5, P7) called for changes to come through schools or Government. While one parent (P5) suggested that physical education (PE) in school should be more varied (*"Perhaps for children who are not particularly 'sporty' there could be different options such as dance or other kinds of exercise to music"*), another asked for PA as homework (*"One day per week when academic homework is replaced by physical activity (and recognised in the same way that homework would be)"* [P7]). P7 also made the following suggestion: *"Lunchtime or break time activities with some sort of structured physical activity (Anna is not motivated to exercise, but if there were some sort of enjoyable activity on offer, she would be more likely to do so)".* Only one parent placed the burden of responsibility on parents, with this answer: *"I personally think getting our children more active needs to start with the parents. If your parents are less active I feel that you will be also"* [P1].

7.5 Discussion

This is the first study informed by the SOS-framework to focus on parental perceptions of their children's SBs. Despite the small sample size, parents in this study identified with most of the factors relating to all six clusters of determinants of SB according to the SOS-framework. There are 43 factors in total listed by the expert group that are thought to influence the SBs of youths, and only 8 of those were not highlighted by parents in this study nor identified by the researcher through other questions. Table 7.9 summarises all the factors, adapted from Chastin et al. (2016b) to highlight the *new* factors identified during the present study as well as the ones participants put in their lists of top 5 factors influencing their children's SBs. Results confirmed that, according to the participants, the majority of the expert group's factors pertaining to youths are applicable to children aged 9-10 years. Researchers planning interventions for this age group can therefore start by consideration of the factors identified in the 'Institutional and home settings' cluster, as recommended by the expert group.

Table 7.9 also shows which factors the researcher consider the most salient in each theme. Some factors were only identified by participants through checking them via the SOS-framework list. For factors to be considered salient, they had to be identified across various interview answers and/or included in participants' list of top 5.

When discussing factors relating to physical health and well-being, parents often talked about their own health in reference to their answer. Chastin et al. (2016a) emphasises that any factors can relate to the individual or the group, as in the case where the parent feels they do not always have the necessary ‘energy’ to be active as a family. These results suggest that the factors influencing the SBs of children in this age group are closely linked to their parents’ physical health and well-being.

Within the social and cultural context, participants often cited a lack of time as a factor that results in increasing their children’s levels of SB. The SOS-framework factor corresponding to this is *time with parents*, defined as “the amount of time children spend with their parents” (Chastin et al., 2016b) and it links to parents being gatekeepers of their children’s physical activity (Noonan et al., 2016a), often unable to take them out resulting in staying at home and engaging in SBs. A new factor identified in this cluster, *physical activity requires planning*, together with a new factor in the politics and economy cluster, namely *financial restraints,* perhaps indicate that some parents have a perception that physical activity needs to be structured or organised, e.g. a sports club or class that children attend (usually at a financial cost). This perception is also evident in participants’ suggestions for future interventions, with most calling for government funding to schools or local groups, in order to reduce the cost of after-school activities. Indeed, it seems that some participants do not see PA as an opportunity for the family to do something together, but rather an activity the children need to be taken to (often driven to), that will occupy some of the parent’s time. Participant 4’s account of their neighbourhood not being safe enough for the children to go to the park alone, resulting in *“...I have to have the time to accompany them”*, reveals that she is not engaged in the activity herself but merely acts as a supervisor or chaperone.

Neighbourhood safety and –walkability / cycle-ability were high on participants’ lists of factors in the built and natural environment cluster. Participant 5’s comparison between the UK and

Uganda and her suggestion that increased walkability might lead to increased neighbourhood safety is consistent with results from a previous study (Noonan et al., 2016a), that found not knowing their neighbours (lack of neighbourhood social cohesion) prevented parents from allowing their children to play alone outside.

Within the psychology and behaviour cluster, parents cited *term time/holiday* as a factor, and believed their children are less sedentary during the holidays. Previous studies have mainly focussed on the seasonal variations of PA and SB (not whether it was term time or holidays), for example a UK-based study (Pearce et al., 2012) that found children's ST to be lowest during the summer. There is also contrasting evidence such as a review of studies whereby findings regarding seasonal variation of SB were inconclusive (Rich, Griffiths and Dezateux, 2012) and a US-based study found an increased amount of screen-based behaviours during the school holidays (Rich, Griffiths and Dezateux, 2012). *Motivation* was identified as a factor within the psychology and behaviour cluster. This result suggests that the expert group's factor pertaining to older adults named *psychology (attitude / temperament / motivation)* is also applicable to children.

The expert group identified the factors relating to the institutional and home settings cluster as having the highest modifiability and potential for behaviour change at population level. *Access to screen-based devices* is the factor most often identified from this cluster. Results from this study suggest that even though parents are the providers of screen-based devices and the rule-makers of its usage, they often struggle to enforce their own rules and end up feeling frustrated and powerless. Parents perhaps need as much support when tackling the SBs of their children, as the children themselves. Family-based interventions should aim to influence parents' misconceptions about PA (their perception that it has to be organised, at a cost), help them identify cost-free PAs enjoyable for the whole family and provide them with parenting tools to reduce screen time at home.

Table 7.2 Factors influencing the sedentary behaviours of youths, according to the expert group and participants in the present study (adapted from Chastin et al. (2016b).)

Physical Health and Wellbeing	Social and Cultural settings	Psychology and Behaviour	Built and Natural Environment	Institutional / Home settings	Politics and Economy
Physical fitness / skills†	Type of TV programmes	Eating in front of TV	Safe surroundings	Rules regarding TV time / computer	Advertising
Energy level†	*Media coverage portrayal of SB*	SB level (past & present)	Recreational facilities	Computer use in school†	Physical education
Mental health†	Family habits / modelling parents, siblings†	PA level (past & present)	Design of public spaces	*Physical organisation and furniture of place of education*	Collectivist norms / attitudes
	Social desirability†	Snacking	Neighbourhood safety†	Outdoor playtime	Public health campaign
	Time with parents†	School attendance†	Urban planning	Accessibility to the internet†	**Financial restraints**
	Pressure (Academic / productivity)	*Self-efficacy*	Neighbourhood walkability / cycle-ability†	Access to screen based devices†	
	Carer's TV viewing time	Differences in preferred mode of transportation	Green / blue areas	Pet ownership	
	Positive social norm to screen use	Modelling the behaviour of others†		Number of screens in dwelling place†	
	Peers (friends or colleagues) †	**Term time / holiday**		*TV in bedroom*	
	Behaviour of peers and friends	**Motivation**		*Number of breaks during day occupation (school / work)*	
	Social network			Access to garden†	
	Cultural view of leisure time†			*Institutional policy*	
	Overprotecting peers / carers			Necessity to use computer after work / school e.g. e-homework†	
	Cultural health beliefs about PA			Type of housing	
	Number of kids in the house†			Commitments to and within family / expectations	
	PA requires planning			Social media†	
	Finding activities enjoyable for whole family				
	Homework load				

Note: Factors in **bold** are those newly identified by participants. Factors in *italics* were *not* identified / selected by participants. † = Factors included in lists of top 5. Underlined factors are considered the most salient.

The e-interview method has several strengths. Parents could answer at a time and place that was convenient for them. This was particularly true for Participant 5, who answered the first few rounds of questions while in Kenya for the summer. It took her longer than most to finish the interview, as they travelled to Uganda to visit friends where she did not have internet access. Eventually, she finished the interview after returning to the UK. It is likely that she would have dropped out if another method was used. While the participant response rate of the present study was quite low (23%), it does not compare unfavourably with similar family-based studies, for example 25% (Noonan et al., 2016a) and 29% (Oh et al., 2017). Both of these studies rewarded participants with monetary incentives, which was not the case in the present study.

While the method was convenient and cost-effective, it also has limitations. Despite asking the participants to answer each email within one week, most of the time they took longer to respond. Two participants finished the whole interview within a few days, however, the rest took about three months each to finish. Follow-up emails were sent in case they had forgotten, but discontinued if they did not respond after two emails. In the case of the present study, sufficient time was available to be patient and allow participants to respond in their own time, however this might not always be possible. The problem with delayed responses (even when time is not an issue) is the uncertainty it creates for the researcher, as the reason behind the delay is unknown (Bampton and Cowton, 2002). This uncertainty can prevent the researcher from probing for further information or clarity, and might result in a lack of the depth obtained during a traditional, face-to-face interview. Researchers should consider the limitations when deciding whether or not to use the method, especially when time to complete a study is limited due to funding.

Finally, the small homogeneous sample size should not be considered representative of all parents/carers. Future studies should aim to interview fathers as well as mothers, which might lead to perceptions on SBs not discussed in this study. Alternatively, future studies might choose to engage the children themselves (using suitable methods) in order to gain perspectives on their own behaviour.

Researcher reflections on the strengths and limitations of the e-interview method

During the e-interviews I was confronted with the uncertainty of delayed responses twice: once after asking a participant to expand on a previous comment she had made, and another time after I asked a participant a specific question regarding her child's gaming habits (which were revealed to me in Study 3). In both cases, there were delayed responses, which made me reflect as to whether the questions were too personal and might have caused offense. Fortunately, most of my participants gave lengthy and detailed answers to interview questions, however, two kept their responses very short, only offering 3-4-word answers per question. As it was already a struggle to get them to respond to emails, I was cautious that I might induce dropout by asking for more details. In a face-to-face interview, it might have been easier to ask them to expand on any given answer. A mixed-method approach, whereby the e-interview is followed up with a telephone call to consolidate, might eliminate these uncertainties.

While I believed I had considered every possible ethical issue that might arise, I did not anticipate that this would be an emotive topic for some. One participant in particular, expressed her great concern over her child's SBs with the previously mentioned quote "I watch my child slowly becoming a person that I do not recognise". I responded sympathetically that I understand her frustration with screen-based devices and that I too find managing it a challenge. However, in hindsight, she might have needed more support. Future researchers *using the e-interview method should identify professionals who can help participants needing more support after discussing a topic that might trigger such an emotional response. Referring the participant to someone qualified to help them deal with their issues will ensure that the research method do not cause any harm to participants.*

My sample only included mothers. This was not by choice, but rather a result of the recruiting process. Mothers most often were the ones completing consent forms for Study 3, therefore were the first point of contact for Study 4 recruitment. Interviewing fathers or other types of family units might have led to new perspectives being explored. Ideally, in cases where both parents are involved in the child's life (whether living in the same house or not), interviewing both would give a more in-depth look into the family dynamic and the factors influencing the child's SBs. I chose to interview parents (as opposed to the children themselves), as they play a vital role in their 9-10 year old's lives and their perspectives will give insight into the influencing factors of SBs. As a mother, I had my own views about our children's SBs and was curious to see whether other parents felt the same. Interviewing the children themselves is also important, as it might bring completely different responses. However, that was beyond the scope of this thesis and should be considered for future studies.

Finally, in an attempt to reduce the effect of researcher bias, I constantly reflected on my own views and assumptions about children's SBs. However, I acknowledge that me being a parent of a child in Study 3 sometimes blurred the lines between researcher and participants. Members of the supervisory team acted as critical friends, challenging my assumptions, but they are also parents, perhaps resulting in some extent of researcher bias being present.

7.6 Conclusion

This study confirms that the factors identified during the development of the SOS-framework are representative of the factors perceived by parent participants to have an influence on their children's SBs. Additionally, six new factors, not listed by the expert group, were identified. These are *PA requires planning*, *finding activities enjoyable for the whole family*, *homework load*, *term time/holiday*, *motivation* and *financial restraints*. These results show how the participants perceive PA as an activity that needs to be planned / structured or organised, at a financial cost. Some of the new factors identified were also related to PA, not only SB. Parents felt that as PA requires planning, effort and financial resources, the only alternative is to stay home, thus increasing their SB by spending more time in front of screens. An important step towards the ultimate goal of reducing children's SBs is to change parents' misconceptions about PA and to support them in their battle against screen-based devices.

Thesis study map

Study	Aims and key findings
Study 1: Establishing raw acceleration thresholds to classify sedentary and stationary behaviours in children	**Aims:** 1. To compare the raw accelerometer output of ActiGraph (AG) and GENEActiv (GA) accelerometers across different placements, 2. To identify raw acceleration signal thresholds for different sedentary behaviours in children, from both the hip and wrist, using AG and GA, 3. To validate the thresholds during free-living activities. **Key findings:** • Hip worn AG monitors resulted in significantly lower acceleration output compared to wrist worn monitors, and are not comparable. • Statistically significant differences between accelerometer outputs of sedentary activities were observed, however these differences are unlikely to be meaningful in practice. • Inconsistent differences between GA and AG monitors were observed during calibration, however free-living data confirmed that the differences were small and unlikely to be meaningful in practice. • Sedentary and stationary thresholds were developed for AG hip, AG and GA non-dominant and dominant wrist placements. • The sedentary thresholds slightly overestimated free-living sedentary time compared with activPAL. The stationary thresholds underestimated stationary time according to activPAL.
Study 2: Validating the Sedentary Sphere method in children.	**Aims:** 1. To validate the Sedentary Sphere method of classifying posture, in child populations using GENEActiv and ActiGraph GT9X wrist-worn accelerometers

	Key findings: • During most observed activities posture classification was high (~78%), irrespective of brand or placement. • "Standing with phone" was misclassified most of the time. • Classification accuracy during free-living was consistent with observed activities (77%), but the method underestimated sitting time compared with activPAL.
Study 3: Exploring a novel mixed-methods approach to assess children's sedentary behaviours.	**Aims:** 1. To explore the efficacy of using accelerometry in combination with a digitalised data capture tool, the Digitising Children's Data Collection (DCDC) for Health, in order to capture children's SBs more comprehensively. **Key findings:** • The DCDC app can be used to add contextual data to accelerometer results, thus capturing SB comprehensively. • Participants spent 629 (SD = 51) minutes per day below the 50m*g* threshold. • DCDC app data revealed that most out-of-school free time was spent using a variety of screen-based devices. • ST according to accelerometry increased over weekends, while app data confirmed this with increased amounts of screen usage reported over weekends. • There was no statistically significant difference between girls' and boys' ST according to accelerometry. • App data revealed differences in screen-based behaviours, with boys preferring to play video games while girls spent time on mobile phones, laptops and tablets. • Playing with toys, arts and crafts, reading and homework were activities reported through all tools (photos, drawings and voice recordings). • On an individual level the app often explained irregular patterns of SB and PA observed through accelerometry.

Study 4: Parental perceptions of the factors influencing children's sedentary behaviours.	**Aims:** 1. To determine if parents' perceptions of the factors influencing children's SBs are the same as those identified by an expert scientist working group, 2. To identify any factors influencing children's SBs not listed by the expert scientist group, and 3. To acquire parents' input and recommendations for future interventions aiming to reduce children's SBs. **Key findings:** • Results confirmed that the factors identified by the expert scientist working group during the development of the SOS-framework, are representative of those factors that parent participants perceived to have an influence on their children's SBs. • Six new factors were identified, relating to both SB and PA. • Future intervention should aim to change parents' misconceptions about PA and support them in their battle against screen based devices.

CHAPTER 8

SYNTHESIS OF FINDINGS

8.1 Introduction

Over the past decade, a large amount of research has been published investigating children's SBs, and this body of research is growing rapidly. However, with no standardised method of assessing the behaviour, researchers are unable to compare the results from different studies and drawing conclusions concerning the behaviour's association with health outcomes remains a challenge. The primary aim of this PhD was to explore and develop new and existing methods of assessing SB in children. This aim was achieved by identifying raw acceleration thresholds for children's SBs (Study 1), validating the Sedentary Sphere method in children (Study 2), adding contextual information to accelerometer data through the use of a digitalised data capturing tool (Study 3) and by gaining information on parental perceptions regarding children's SBs via e-mail interviews (Study 4). This synthesis summarises the findings from Studies 1 to 4, highlights the strengths and limitations of the research, critically reflects on the challenges faced by and opportunities available for researchers in this field, summarises the implications of this thesis for researchers and public health policy as well as presents recommendations for future research and practice.

8.2 Summary of findings

Study 1 first compared raw acceleration output of AG and GA across three different placements during five sedentary and two LPA intensity activities. Some findings, like the lower accelerometer output observed from hip monitors compared with wrists, were consistent with previous research (Fairclough et al., 2016; Hildebrand et al., 2016). Data from the dominant wrist produced higher accelerometer outcomes compared to non-dominant wrists, consistent with results from Buchan, Boddy and McLellan (2019). Other results were unique to this study, giving insight into the nature of children's SBs. Unexpectedly, for example, the homework station produced the overall lowest accelerometer output of all the stations, even lower than TV viewing and resting. This emphasises how little movement is required for copying a piece of writing. The stationary activity 'standing with phone' produced the second lowest accelerometer output from wrist monitors and the lowest output from hip monitors. This finding highlights the inability of the threshold approach to differentiate between postures, as such low accelerometer outputs will be classified as 'sedentary' when using this method. Differences were observed between monitor brands, but as these yielded small effect sizes, they are unlikely to be meaningful in practice.

Study 1 also identified raw acceleration sedentary and stationary thresholds. This was the first study to generate thresholds from a wide range of sedentary activities using the ENMO metric. During a period of free-living, the non-dominant wrist sedentary thresholds (AG 48 m*g* and GA 52 m*g*) *overestimated* ST according to activPAL, while the stationary thresholds (AG 58 m*g* and GA 61 m*g*) *underestimated* stationary time. Both thresholds reached equivalency with activPAL at the 15% zone of equivalence, but the various indicators of measurement agreement showed that the sedentary thresholds performed better during free-living than the stationary thresholds. The AG 48 m*g* sedentary threshold came the closest to achieving equivalency within 10% of the activPAL mean, on average at the group level. Both the AG 48 m*g* and GA 52 m*g* thresholds are similar to a recently published GA threshold of 51 m*g* (Boddy et al., 2018), while 50 m*g* has recently been used in the literature (Rowlands et al., 2018a). Researchers can use these thresholds to estimate ST, but should acknowledge that it will likely include some stationary time as well.

The threshold approach is unable to capture posture, a fundamental element of SB measurement that is central to its definition. Study 2 addressed this gap by being the first study to validate the Sedentary Sphere method of classifying posture from wrist-worn accelerometers in children. Posture classification accuracy was similar (around 78%) for observed activities, during break time as well as during one day of free-living, irrespective of monitor brand. During observed activities, 'standing while playing with a mobile phone' was mostly misclassified, similar to results from adult studies where standing activities requiring arm elevation (like washing-up) resulted in misclassification of posture (Rowlands et al., 2014). The impact of mobile phone use on posture estimation during free-living settings in children is unknown. Even though the Sedentary Sphere method performed equally well (epoch-by-epoch agreement) in different settings, free-living ST was underestimated by about 10% compared with data from activPAL. The results from this study showed that while the Sedentary Sphere method can be used to predict the *most likely* posture, the algorithm needs refinement for more accurate estimates of children's ST.

Accelerometry allows researchers to quantify time spent in various movement intensities, and now researchers are also able to estimate the most likely posture from wrist-worn devices in children, by using the Sedentary Sphere method. However, accelerometer data lacks contextual information about the types of SBs children engage in. Researchers have been calling for studies to use a combination of accelerometry and self-report tools in children in order to capture SB more comprehensively (Lubans et al., 2011; Lima et al., 2019). Study 3 attempted to address this by assessing SB through both accelerometry and four different data capturing tools of the DCDC app. Participants captured their daily SBs through photos, drawings, voice recordings and a multiple-choice questionnaire.

Accelerometer results from Study 3 showed that participants spent more than 10 waking hours per day (mean = 629 min) below the 50 m*g* threshold. Sedentary Sphere analysis revealed that about 48% of waking time included in the analysis was spent in sitting or lying postures, but as established in Study 2, this result is likely an underestimation of ST. Consistent with previous research (Steele et al., 2010), ST estimates were higher on weekend days than weekdays. The DCDC app data revealed that this is likely due to increased amounts of TV viewing and video gaming during weekend days, to the extent that it exceeded their time spent sitting during school days. While there was no significant difference found in boys' and girls' ST estimates, girls had significantly lower (steeper) intensity gradients than boys, which is associated with unfavourable changes in health indicators (Fairclough et al., 2019b).

According to the DCDC app data, participants spent most of their out-of-school time engaged in screen-based behaviours. App data also revealed that TV viewing was not the main screen-based activity for participants. Instead, girls preferred to watch YouTube videos and movies on tablets or laptops, or spend time on social media, while boys played video games. This finding suggests that intervention design should be gender-specific. Other sedentary activities reported across all data capturing tools (i.e. photos, drawings and voice recordings) were playing with toys, reading, arts and crafts as well as homework. On an individual level, the app often explained patterns of SB and PA observed in accelerometer results. The app demonstrated the potential to capture previously unknown, rich contextual data about the whole 24-hour movement continuum for each participant. The app could be used prior to intervention formatively to identify specific behaviours to be targeted, or during evaluation to observe changes in behaviour.

The methods proposed in Studies 1 to 3 provide researchers with ways to assess children's ST, as well as a potential way to examine the types of sedentary activities children engage in. However, in order to design effective interventions aiming to reduce some of these behaviours, more information is needed as to *why* children spend so much time engaged in SBs. Study 4 investigated the factors influencing children's SBs, through email interviews with parents from child participants of Study 3. This study was the first to focus on parental perceptions of children's SBs, informed by the recently published Systems of Sedentary Behaviours framework (Chastin et al., 2016a).

Parent participants of Study 4 confirmed that the list of factors influencing the SBs of youth, as published by an international expert scientist working group (Chastin et al., 2016b), was applicable to the 9-10-year-old participants from Study 3. While parents identified with most of the published factors, six new factors were identified, which related to PA in addition to SB. These were: PA requires planning, finding activities enjoyable for the whole family, homework, term time / holiday, motivation and financial restraints. These results suggest that the participants see PA as an organised activity that children need to be taken to, at a financial cost. These perceived barriers to PA result in families staying at home, increasing their SBs. Future interventions are necessary to address parents' misconceptions about PA as well as support parents when trying to limit the time children spend using screen-based devices.

8.3 Strengths and limitations

A key strength of this PhD is the variety of quantitative and qualitative methods used to measure and explore children's SB. These include raw acceleration data analysis using thresholds, the Sedentary Sphere method as well as new metrics like the intensity gradient and average acceleration. Self-report methods via the DCDC app included photos, drawings, voice recordings and a multiple-choice questionnaire. Qualitative data from parents regarding factors influencing children's SBs were obtained through email interviews. Study specific strengths and limitations were discussed in the relevant chapters, but key strengths and limitations will briefly be summarised here.

During the calibration protocol of Study 1, participants wore six different monitors each, during seven observed activities as well as 10 minutes of free-play time. Raw acceleration data processing allowed for various comparisons to be made between monitor brands and placements. Free-living results from Study 2 confirmed that the protocol in the gymnasium had ecological validity. Recall errors typically associated with self-report in children were minimised in Study 3 by asking participants to report their SBs daily through the DCDC app. The four data collection tools used by the app complemented each other and allowed for data triangulation. Using the app in combination with accelerometry strengthened the results by adding important contextual data to time spent sedentary. Interviewing parents via email allowed both parties to complete the interviews at times and places that were most convenient.

Key limitations of the studies presented in this thesis are sample size, selection bias and generalisability. The sample size for Studies 1 and 2 was decided based upon similar studies and feasibility. Even though the sample size of 27 seems small, it compares favourably with similar calibration studies (e.g. n=20 (Aittasalo et al., 2015), n=30 (Hildebrand et al., 2016)). The sample size for Study 3 was informed by the aim, design and manageability of the study. The aim was to explore the efficacy of a new mixed-method tool, allowing the researcher to choose a sampling scheme of convenience (i.e. choosing settings and individuals available and willing to participate (Onwuegbuzie and Collins, 2007)). Analysing both qualitative and quantitative data, collected concurrently from the same participants, is time consuming and therefore the decision was made to stop recruiting and collecting data after reaching a sample size of 74. As the study's objective was exploring the use of a new method, rather than drawing conclusions from the actual results, detail was favoured over sample size, and we acknowledge that the methods would require further testing/exploration in different groups (e.g. adolescents, young children etc.) to describe SB of young people more comprehensively. The small sample size of Study 4 is a result of a high drop-out rate. Despite 14 potential participants giving their consent to be interviewed by completing the online survey, only 8 responded to the emails. Reasons for not responding are unknown and the small sample size is a limitation. It is unlikely that data saturation was achieved, as new codes were still identified during the last full interview. Recruiting more participants including fathers, might have led to perceptions on SBs not identified in Study 4.

Recruiting schools for Study 3 proved to be a challenge. More than 30 schools in and around Liverpool were contacted via email, and most did not respond. Three of the four schools eventually recruited had a link to someone at the Physical Activity Exchange, perhaps resulting in selection bias being present. However, obtaining gatekeeper consent was only the first step in the recruiting process and would not have had an impact on the results from the child participants. Three of the four schools are situated in high deprivation areas (IMD deciles of 2 and 3) in and around Liverpool. While the fourth school is located in a more affluent area (IMD decile of 8), the majority of its participants were from high deprivation areas (IMD deciles of 1 and 2). Children from high deprivation areas are more likely to have higher levels of overweight and obesity than low deprivation areas, as well as lower fitness levels (Noonan et al., 2016d). However, the aim of the study was to explore a new method, therefore, participants' socioeconomic status should not have affected the feasibility and acceptability of the results.

Participants' levels and types of SBs reported however should not be considered representative of the larger UK population, as these results might be different from those in low deprivation areas.

Studies 1 to 3 focussed on 9-10 year olds, as this is the same age group that would likely be targeted in future interventions aiming to establish good PA and SB levels and habits, before the known decline in PA levels occur in adolescence. A second reason for choosing this age group is a practical one, that primary schools are more likely to allow researchers access to Year 5 children, as unlike Year 6 children, they do not have to prepare for standard assessment tests. This age group should not be considered representative of all ages. The eight participants from Study 4 were all mothers, and seven of them were of white, British ethnicity. Five participants were university-educated. These participants indicated on consent forms from Study 3 that they would be willing to participate in Study 4. It is likely that they expressed their willingness to be recruited as a result of being interested in the topic of their children's SBs and therefore selection bias might have been present. These participants were parents of children from two schools (in Liverpool and Widnes) and should not be considered representative of a wider population.

The use of activPAL as a criterion reference during the calibration protocol of Study 1 and part of Study 2, as well as during the periods of free-living can be seen as a limitation. Study 1 highlighted that activPAL sometimes misclassified periods of sitting as standing in children, and it has to be assumed that this might have happened to some degree during free-living as well. However, no other tool exists that can be used in a free-living setting, except for direct observation, which in turn has the potential for participant reactivity and is often unfeasible.

Limitations of Study 3 mainly include non-compliance by participants and the volume of 'irrelevant' data generated. Children often ignored the questions asked and gave unrelated answers. These however, might perhaps be expected when piloting a new method, and should be overcome by following the resultant recommendations made for future use of the app.

The e-interview method used in Study 4 has limitations as well. Delayed responses sometimes created uncertainty for the researcher and more depth might have been achieved with face-to-face interviews. Researcher bias could not be completely eliminated as both researcher, her critical friends as well as the participants were parents (mothers).

8.4 Critical reflection of the field and implications for the future

The behavioural epidemiology framework informed this thesis, as discussed in Chapter 1. The framework describes the six phases of research that lead to changes at policy level (phase 6). This thesis focussed mainly on phase 2 (measuring the behaviour). Okely et al. (2018) argues that phases 1 (identifying relationships of SB with health outcomes) and 4 (identifying determinants of SB) can be seen as building blocks for phases 5 (interventions) and 6 (changing public health guidelines and policy). However, a weak or flawed phase 2 might lead to inaccurate evidence of the links between SB and health as well as an inability to assess the effectiveness of interventions accurately. Phase 2 therefore is key, informing all the other phases. Studies 1, 2 and 3 focussed solely on phase 2, increasing the accuracy by which we measure the behaviour using multiple methods. Study 4 added to our understanding of the influencing factors of the behaviour (phase 4).

Researchers interested in advancing the field of children's SB face a number of challenges. For those using accelerometry, the question of which accelerometer metrics to use for analysis can be a daunting one. The newly published metrics like intensity gradient and average acceleration focus mainly on PA, so using the threshold method is still a requirement when studying SB. Deciding which thresholds to use has always been a challenge for researchers. Raw data analysis is recommended (Freedson et al., 2012) and the raw acceleration thresholds identified in Study 1 can now be used to classify ST. While these thresholds slightly overestimated sitting time, researchers can use it with confidence that it captures ST as accurately as possible with the thresholds method. By using GGIR, the new metrics can easily be processed simultaneously with thresholds, thus adding additional dimensions to the results. A second challenge faced by researchers wanting to accurately classify ST is distinguishing between the postures sitting and standing. The Sedentary Sphere method of classifying posture underestimated sitting time in free-living children in Study 2. This work might prompt the developers of the method to refine it for child populations. Possible improvements to the method include adding features like patterns of movements within angles, patterns of changes in angles or adding a frequency domain.

Perhaps the biggest challenge faced by those assessing SB with accelerometry is capturing the various types of behaviours included in the definition of SB. Even with machine learning advances in technology, it is unlikely that an accelerometer will ever be able to distinguish between types of activities while sitting, settings in which the behaviours take place or the number of people engaged in the activity. This thesis presented a feasible solution for this challenge with the use of an app in combination with accelerometry. It also presents numerous possibilities for the field to move forward, by paving the way for future studies. Study 3 showed that the tools used by the DCDC app (voice recordings, photos and drawings with written/spoken descriptions) can capture detailed information regarding children's SBs. Future studies might use the app to answer domain-specific questions about children's SBs. Alternatively, the same tools can be used in newly developed apps for population based studies. These studies will provide researchers with a clearer picture of the current levels of SBs in child populations, specifically the amount of screen-based behaviours, and its relationship with health outcomes. Subsequently, national public health guidelines for reducing SBs might be introduced. Currently the UK government guidelines state that children should aim to minimise ST, with no specific guidelines regarding screen time. Quantitative guidelines regarding screen time will present public health officials with an easier message to communicate to the public through GP surgeries, schools and community initiatives. Whilst the parents in Study 4 felt that changes in children's SBs should come through school and government initiatives, Study 3 clearly showed that vast amounts of screen-based activities are taking place in home settings. Parents therefore, should share the burden of responsibility, but perhaps are in need of support as to finding effective ways of tackling these behaviours. Public health officials can easily reach parents through schools, and offering parent support classes might be a starting point. Classes should aim to inform parents of the risks linked to too much screen time, identifying warning signs and strategies to reduce their children's screen-based behaviours.

The DCDC app (or similar apps using the same tools) can also be used in smaller studies aiming to identify at-risk children. With commercial wearables becoming more accurate, a future app might be developed for use in combination with such devices. Such an app can be either used for research purposes or for families' private use. Weekly results sent to researchers or parents in the form of a dashboard can help monitor children's at-risk behaviours. Tracking children's online behaviour this way, however, presents an ethical challenge for researchers. Children as well as parents would have to sign informed consent, permitting researchers to use their data.

Finally, researchers face the challenge of keeping up with the fast-paced nature of technology that constantly changes children's screen-based behaviours, depending on the next trend. These trends can cause an increase in ST, e.g. a popular video game like Fortnite, which children spend hours playing (as evident from the results of Study 3). Other trends might decrease ST. Social media trends like the popular dance video app "TikTok" has the potential to increase PA through perfecting your dance moves before uploading your video. Researchers as well as parents need to stay updated on the latest trends in order to target behaviour, and results from Study 3 showed that the DCDC app is able to identify these trends.

8.5 Reflections

I successfully defended this thesis on March 5, 2020. In the almost three months that have passed since writing the above, the coronavirus disease 2019 (COVID-19) pandemic hit the UK, with the government enforcing a lockdown of all but essential businesses and services, in an attempt to slow the transmission of the disease and to ease the burden on the National Health Service. Researchers worldwide are expressing their concern over the social, physical and mental health consequences for children during the pandemic, because of school closures (Hall et al., 2020; Rundle et al., 2020; Wang et al., 2020).

Shortly before the lockdown, I did a few presentations at our children's school during Science week, discussing my research with Year 4 and 5 children as well as their teachers and some parents. Conversations with parents confirmed the results from Study 4, which suggest that parents need support in tackling their children's SBs, particularly screen-based behaviours. During lockdown, the UK government allowed for outdoor exercise once a day, which might have resulted in children meeting the government guidelines for PA, as families took the opportunity to go out for exercise. SBs however, are also likely to have increased, as the rest of the day children were confined to their homes. This is especially true for those without access to a garden. Van Lancker and Parolin (2020) predict that prolonged school closures will worsen existing health inequalities. Wang et al. (2020) points out that good parenting skills are particularly crucial during times like these, highlighting the urgency of the above-mentioned finding.

As the UK and the rest of the world slowly come out of lockdown and “return to normal”, researchers, public health officials and teachers must be vigilant of the long lasting effects that the lockdown might have had on children. Research is ongoing, but there is already evidence of rising online video game usage (Wilde, 2020). Some children might have become addicted to video gaming and these need to be identified quickly, in order to effectively intervene. Now, more than ever we need to tackle this problem as a matter of urgency.

Finally, on a personal note, conducting this research has been a very rewarding experience. I have had the opportunity to work with some of the leading researchers in this field. I have gained knowledge, but more importantly, developed skills through using a wide range of qualitative and quantitative research methodologies. My own thoughts and ideas about children’s SBs, shaped mainly by my children’s behaviours, were challenged throughout the research process by members of my supervisory team as well as child and parent participants in my studies. For this I am truly grateful. This work has given me an appreciation for the challenges researchers face when investigating a behaviour as important and complex as SB. It has truly been a joy and a privilege!

8.6 Conclusions

This thesis has refined existing methods of SB measurement as well as added new methods of assessing SB in children to the literature. The complexity of SB continues to challenge researchers aiming to measure the behaviour accurately. If researchers could start using consistent methods of assessment, we might overcome this challenge. This PhD identified the 48 m*g* raw acceleration threshold as the cut point coming closest to capturing ST accurately. However, it is important that researchers should adopt a consistent approach, therefore a threshold of 50 m*g* seems appropriate and would make little practical difference in terms of measured ST. Study 2 showed that the Sedentary Sphere method holds promise but needs refining to improve the accuracy of children's ST estimates. Study 3 represents a novel mixed method study combining accelerometry with the DCDC app and shows the potential to capture the whole 24-hour movement continuum, adding valuable contextual information to children's accelerometer data. Study 4 investigated factors influencing children's SBs and areas to target within future interventions were identified as a result.

8.7 Recommendations

In light of the findings presented in this thesis, the following recommendations are made for 1) researchers aiming to assess children's SBs or designing interventions, 2) software developers of the DCDC app or those developing new applications.

8.7.1 Recommendations for researchers

- Data from hip and wrist monitors should not be compared, unless effective data harmonisation approaches are used.
- When applying thresholds to raw accelerometer data, researchers should use 50 m*g* as the cut point for ST estimated from the non-dominant wrist placement.
- Researchers should acknowledge that threshold methods do not provide an exact measure of ST, and are likely to include time spent standing still. The inability of the threshold approach to differentiate between postures means time spent below 50 m*g* is more likely an indication of sedentary and stationary time.
- The Sedentary Sphere method could be used with caution, knowing that it underestimates ST in children by about 10%. The method can be applied to either GA or AG, dominant- or non-dominant wrist data which should result in similar outcomes.
- Direct observation should be used to determine the extent of children's free-living mobile phone use, specifically to find out whether they are spending time on mobile phones while standing still, walking or sitting.
- Refine the Sedentary Sphere algorithm for child populations. This might include adding features like patterns of movements within angles, patterns of changes in angles or adding a frequency domain.
- Use accelerometry in combination with the DCDC app to capture SBs or the whole 24-hour movement continuum, by designing studies to answer specific research questions through photos, drawings, voice recordings and multiple-choice questionnaires.
- When using the DCDC app (or similar) use 'non-research questions' in order to reduce irrelevant data. For example a generic (non-research) question like "What did you do today?" could precede a more specific question like "What did you do while sitting /

lying down today?" This might reduce unrelated content, as well as help participants to give more focussed answers.

- Researchers should consider developing online resources explaining study procedures, for example a video detailing accelerometer wear as well as app usage. This can be shown in class as well as sent to parents as a link via email or text.
- When designing interventions to reduce children's screen-based SBs, consider the differences observed in Study 3 between boys' and girls' screen-time behaviours. Interventions to replace some of the time boys spent playing video games, should aim to reach the same feelings of achievement attained through gaming that has been shown to improve their self-esteem. Interventions designed for girls should include a social element, giving girls the opportunity to connect with their friends in real life as opposed to social media.
- As also recommended by the SOS-framework's authors, researchers designing interventions aiming to reduce SBs of children should start by focussing on factors identified in the home and institutional settings cluster, as these are deemed the most modifiable.
- Parents should also be a targeted in SB interventions, either as part of a family-based intervention or as a group on their own. Parents might need support in how to set and maintain boundaries for screen usage.
- Aim to change any misconceptions about PA that parents might have, e.g. that PA needs to be organised and planned at a financial cost.
- Investigate how much homework children receive, how long it takes them per day and whether the volume of homework during the primary school years is necessary or could involve homework that targets reducing SB.

- When using the e-interview method, researchers might consider a mix-method approach by following up the final email with a telephone conversation to check that responses were interpreted accurately.

8.7.2 Recommendations for software developers

- Streamline data output from the DCDC app (or similar, newly developed application). Data output should preferably consist of one file per participant, including all the time- and date stamped results from the various data collection tools. A separate output file should contain the combined results from all participants.
- Add an interactive feature to the DCDC app (or other applications designed to capture children's health behaviours), allowing the researcher to communicate with participants during data collection periods.

CHAPTER 9

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CHAPTER 10

APPENDICES

APPENDIX A: Study 1 - Parent / carer information sheet

LIVERPOOL JOHN MOORES UNIVERSITY

PARENT/CARER INFORMATION SHEET

Project title: Establishing raw acceleration thresholds for sedentary behaviour in children

Name of Researchers and School/Faculty: Liezel Hurter, Dr. Lynne Boddy, Dr. Zoe Knowles (Research Institute for Sport and Exercise Sciences), Dr Lorna Porcellato (Public Health Institute)

We would like to invite your child to take part in a research study investigating sedentary behaviours. Before you decide, we want you to understand why the research is being done and what it involves. Please take time to read the following information and ask if there is anything that is not clear or if you would like further information. Take time to decide whether you would like your child to take part.

1. What is the purpose of the study?

Physical activity is important for our health but some children don't do enough physical activity, and many spend a lot of time watching television and playing video games which are classed as sedentary behaviours. We want to find out more about how Year 5 pupils are spending their time when they are not active, but first we need to find out a way to measure this better.

2. Do my child have to contribute?

No. It is up to you whether you would like your child to take part in the study. If you are happy for your child to take part, please complete parent/carer participant consent form and the demographic information sheet. Your child will also receive information and will be asked to complete an assent form in order to take part. We ask that you return all items to your child's school.

Even after giving consent your child is still free to withdraw from the study at any time without giving a reason. Withdrawing from the study will not affect your child in any way.

3. What will happen if my child takes part?

Data collection for this study will be in January/February 2017, and if you agree, your child will only be involved on one day, during school hours and on school premises. If weather conditions mean your child is unable to go outside at playtime we will reschedule the playtime part of data collection. To complete the data collection sessions we would like your child to wear their usual school PE kit.

Data collection session	
Height, weight, waist and sitting height	We will measure your child's weight, height, waist and sitting height. All of these measures will take place in the school hall, and no one other than the researchers will see the results. Weight will

	be measured by asking children to stand on a weighing scale with shoes removed. Height and sitting height will be measured using a height meter and a non-elastic measuring tape will be used to measure the distance around your child's waist.
Sedentary behaviour measurement	Your child will be asked to wear six different activity monitors. The monitors are small devices similar to pedometers. Two of these devices look like a watch, another is a smaller device that is placed directed onto the skin using a plaster. We will ask your child to wear two monitors on each wrist, one on the right thigh (this is the one that sticks to the skin like a plaster) and one on the hip. He/she will then be asked to complete seven different stations, spending five minutes at each station. These are the stations: **Resting:** Your child will be asked to lie on a bed or soft gym mat, on his/her back, as still as possible. **Watching television:** Your child will be asked to lie/sit comfortably on a couch or chair, watching an age appropriate television programme or movie. **Sitting, playing with tablet:** Your child will be given a tablet to play with, while sitting on a chair. He/she will be asked to play the Bike Race game. **Playing with Lego:** Your child will be given age appropriate Lego to play with, while sitting at a table. **Writing:** Your child will be instructed to copy a piece of writing, mimicking doing homework. **Standing, playing with a phone/tablet:** The participant will be given a phone/tablet to play with, while standing. He/she will be asked to play the Subway Surf game. This will be offline, not connected to Wi-Fi or 4G. **Walk:** Your child will be instructed to walk, at their own pace around a designated track or circuit.
Physical activity and sedentary behaviour during playtime	Your child will keep the monitors on, while going to playtime. We will observe your child at playtime and make a note of the type of activity your child is engaged in, for example walking around, talking to friends or staff, skipping etc. Children will be encouraged to play as normal. Video recording of participants will be taken within their usual playtime setting. If you do not want your child to be videoed, then observations will be scored 'live'. This will involve taking notes whilst observing your child's activity. This is less reliable than using video methods. Only researchers involved with the project will see the video footage. If video consent is provided three cameras will be set up around the playground area with one researcher operating each camera. Each camera will record one child for a period of ten minutes. Once ten minutes of play has been recorded the data collection has been completed. Using the video footage (or scored live), a scoring

	system will be used to assess how active your child was, and his/her play behaviours. Other data concerning the setting will also be collected, such as whether play equipment is available.

4. Are there any risks involved?

No, there are no risks to your child. Children may feel apprehensive when researchers are taking measures such as height and weight, but we will answer any questions or queries that your child may have and we will do our best to create a positive and supportive environment. No one other than the researchers will see their results. Your child may feel some discomfort similar to removing a plaster when removing the thigh monitor, if your child is allergic to plasters please indicate on the consent form.

Your child's participation in the study is voluntary, and he/she is able to withdraw from the study at any stage of the research process.

5. What are the benefits to my family?

Children typically enjoy being part of these studies. The exposure to the protocol and information given on the study may stimulate interest in sedentary behaviour, physical activity and health as well as an awareness of their own sedentary behaviours.

Children who complete all the stations will receive a £10 Tesco voucher as a thank you.

6. Will my child's participation in the study be kept private?

All information about your child, including the results and findings will be treated with the strictest confidence by the research team. No identifiable information will be released by the project, and all data will be securely stored by project researchers.

If you have any questions do not hesitate to get in touch:

Liezel Hurter – L.Hurter@2016.ljmu.ac.uk or Dr Lynne Boddy - L.M.Boddy@ljmu.ac.uk, 0151 231 4275

School of Sport and Exercise Sciences, Liverpool John Moores University, The Physical Activity Exchange, 62 Great Crosshall Street, Liverpool, L3 3AT.

Thank you for taking the time to read this information.
Feel free to email me at any time.

APPENDIX B: Study 1 – Child information sheet

LIVERPOOL JOHN MOORES UNIVERSITY

CHILD PARTICIPANT INFORMATION SHEET

Title of Project: Establishing raw acceleration thresholds for sedentary behaviour in children

Name of Researchers and School/Faculty: Liezel Hurter, Dr. Lynne Boddy, Dr. Zoe Knowles (Research Institute for Sport and Exercise Sciences), Dr. Lorna Porcellato (Public Health Institute)

Hello, my name is Liezel and I would like to invite you to take part in a project about children's inactivity. Physical activity is important for our health but some children don't do enough physical activity, and many spend a lot of time watching television and playing video games. We want to find out more about how Year 5 children are spending their time when they are not active, but first we need to find out a way to measure this better.

To do this we will:

a. We will measure how tall you are when you are standing up and sitting down.

b. We will measure your weight by asking you to stand on a weighing scale with your shoes off. We will do this at your school, away from other children and only you and the researchers will know your weight.

c. We will measure the distance around your waist using a measuring tape.

d. Then we will put six different activity monitors on you: 2 on each wrist (they look like watches), one on your thigh that we will stick down with a plaster and one on your hip. You will wear this only for about an hour. While you are wearing this we will ask you to do the following for 5 minutes each: lie down and rest, watch television, play with a tablet, play with Lego, write on a piece of paper, stand and play with a phone and finally walk around for 5 minutes.

You will then keep the monitors on during playtime. We will take a video of you to see what you do at playtime. We will also make notes about the area you are playing in, like whether there is any play equipment there.

Do you have to take part?

You don't have to take part if you don't want to. If you decide to take part but don't want to carry on with the project, you don't have to. You can stop taking part at any time, and you don't have to tell us why.

Confidentiality

Any information we collect about you during this project will be kept confidential. This means your name will be taken off and nobody will know it was you. We will not show your information to any one (not even your teachers or your friends).

What will you get?

You will learn more about being healthy and why we shouldn't be too inactive. Also, if you take part in the whole study we will give you a £10 Tesco voucher to say thank you for your time.

If you are interested in taking part in the next stage of the project, this is what you should do next:

1) **Your parent/carer (your mum or dad for example) and you should fill in the forms in this pack called "CHILD ASSENT FORM", "PARENT/CARER CONSENT FORM" and "DEMOGRAPHIC INFORMATION SHEET"**

2) When these forms have been filled in, **you should** return it to your teacher at school by….

Forms received after this date may not be considered for the project.

If you would like to **find out more information about the study,** please ask your teacher or a parent/carer to contact me.

Remember: you can leave the project at any time and you do not have to give us a reason.

APPENDIX C: Study 3 – Parent / carer information sheet

LIVERPOOL JOHN MOORES UNIVERSITY

PARENT/CARER INFORMATION SHEET

Project title: Exploring new methods of measuring children's sedentary behaviour

Name of Researchers and School/Faculty: Liezel Hurter, Dr. Lynne Boddy, Dr. Zoe Knowles (Research Institute for Sport and Exercise Sciences), Dr Lorna Porcellato (Public Health Institute)

We would like to invite your child to take part in a research study investigating sedentary behaviours. Before you decide, we want you to understand why the research is being done and what it involves. Please take time to read the following information and ask if there is anything that is not clear or if you would like further information. Take time to decide whether you would like your child to participate.

1. What is the purpose of the study?

Physical activity is important for our health but some children do not do enough physical activity, and many spend a lot of time watching television and playing video games, which are classed as sedentary behaviours. We want to find out more about how Year 5 pupils are spending their time when they are not being active.

2. Do my child have to contribute?

No. It is up to you whether you would like your child to take part in the study. If you are happy for your child to take part, please complete parent/carer participant consent form and the demographic information sheet. Your child will also receive information and will be asked to complete an assent form in order to take part. We ask that you return all items to your child's school.

Even after giving consent your child is still free to withdraw from the study at any time without giving a reason. Withdrawing from the study will not affect your child in any way.

3. What will happen if my child takes part?

Data collection session	
Height, weight, waist and sitting height	We will measure your child's weight, height, waist and sitting height. All of these measures will take place at school, and no one other than the researchers will see the results. Weight will be measured by asking children to stand on a weighing scale with shoes removed. Height and sitting height will be measured using a height meter and a non-elastic measuring tape will be used to measure the distance around your child's waist. This part of the study will take place at the school.

Sedentary behaviour measurement 1	Your child will be given a Samsung tablet with an app which they will use to answer questions about their time spent at home (like watching TV, playing video games, doing homework etc.). **Internet access will be blocked** and your child will not be able to access anything other than the app. Your child will be asked to make a voice recording, briefly describing his/her day, and take photographs of the spaces and places where he/she spent his/her time. For example your child might take a picture of where he/she sat while doing homework, the television and the couch or the backyard where he/she played. The children will be shown how to use the tablet at school and instructions on use will also be included with the tablet. Children will be asked not to take any photos of people. Your child will keep the tablet for seven days, recording the information once a day. This shouldn't take more than 10 minutes. We will collect the tablet at school after the seven days.
Sedentary behaviour measurement 2	Your child will also be given an activity monitor, to wear on his/her wrist (like a watch) for seven days. A sub-sample of 20 children will be asked to wear two additional monitors: a second watch and a small monitor attached to the thigh with a plaster. One wrist monitor will be worn for seven days, including during sleep, while the other two will be collected by the researcher after two days. Some children will only get one monitor, while others will be asked to wear all three. These will record your child's physical activity. Your child will be asked to remove the wrist monitors before doing any water-based activities like swimming or bathing. We will collect the monitors at school after the seven days.

4. Are there any risks involved?

Children may feel apprehensive when researchers are taking measures such as height and weight, but we will answer any questions or queries that your child may have and we will do our best to create a positive and supportive environment. No one other than the researchers will see their results. Your child's participation in the study is voluntary, and he/she is able to withdraw from the study at any stage of the research process.

We ask that children only take the tablet out of their home environment when in the presence of a supervising adult (for example parent, coach, grandparent) to minimise the risk of theft and damage. For example if your family goes for a walk it would be great for your child to take the tablet along with you, but if your child goes out to play with friends unsupervised we ask that the tablet be left at home.

Your child may feel some discomfort similar to removing a plaster when removing the thigh monitor, if your child is allergic to plasters please indicate on the consent form.

5. What are the benefits to my family?

Children typically enjoy being part of these studies. The exposure to the protocol and information given on the study may stimulate interest in sedentary behaviour, physical activity and health as well as an awareness of their own sedentary behaviours.

6. Will my child's participation in the study be kept private?

All information about your child, including the results and findings will be treated with the strictest confidence by the research team. No identifiable information will be released by the project, and all data will be securely stored by project researchers.

7. What happens after the study?

After this project is completed, the research team would like to do a follow-up study to learn more about parents' perceptions and thoughts regarding their children's lifestyles. If you are interested to speak to us (in a telephone interview or focus group) about your child's results from this study and your views on his/her sedentary behaviour, please indicate so on the consent form.

If you have any questions do not hesitate to get in touch:

Liezel Hurter – L.Hurter@2016.ljmu.ac.uk 077 097 09630
Dr Lynne Boddy - L.M.Boddy@ljmu.ac.uk, 0151 231 4275
Dr Lorna Porcellato – L.Porcellato@ljmu.ac.uk or 0151 231 4201

APPENDIX D: Study 3 – Child information sheet

LIVERPOOL JOHN MOORES UNIVERSITY

CHILD PARTICIPANT INFORMATION SHEET

Hello, my name is Liezel and I would like to invite you to take part in a project about children's inactivity. We want to find out more about how Year 5 children are spending their time when they are not active.

What happens if I take part?

- We will measure how tall you are when you are standing up and sitting down. We will also measure the distance around your waist.
- We will measure your weight by asking you to stand on a weighing scale. We will do this at your school, away from other children and only you and the researcher will know your weight.

- Then we will give you a tablet, almost like an iPad, to use at home for 7 days. The tablet has an app that will ask you some questions about how you spend your time each day (like if you watched TV, played games, did homework etc.). It will also ask you to record your voice and tell us more about your day. You can take photos with the tablet to show us where you spend your days, for example where you are playing and what you are doing. We will ask you NOT to take photos of any people, only of places.

  

- We will also give you three activity monitors to wear. Two look like watches, on your wrist and we will put the third one on your thigh with a plaster. We will ask you to wear one watch for 7 days, and the other two only for 2 days. If you don't want to wear all three, you can only wear one watch for 7 days.

Do I have to take part?

No, only if you want to. If you decide to take part, but don't want to carry on with the project, you don't have to. You can stop taking part at any time, and you don't have to tell us why.

Confidentiality

Any information we collect about you during this project will be kept confidential. That means your name will be taken off and nobody will know it was you. We will not show your information to any one, not even your teachers or your friends.

What are the benefits of taking part?

This project will help us to understand how children spend their free time. When we know that, we can work together with families to try to find ways for people to lead healthier lives.

If you would like to take part in this project, here is what you should do next:

- Your parent / carer (for example your mum or dad) and you should fill in the forms in this pack called "CHILD ASSENT FORM", "PARENT / CARER CONSENT FORM" and "DEMOGRAPHIC INFORMATION SHEET"

- Take the forms back to your teacher.

If you would like to find out more about the study, please ask your teacher or mum / dad to contact me. Remember: you can leave the project at any time and you do not have to say why.

APPENDIX E: Studies 1 and 3 – Demographic informations forms

LIVERPOOL JOHN MOORES UNIVERSITY

DEMOGRAPHIC INFORMATION FORM

Title of Project: Establishing raw acceleration thresholds for sedentary behaviour in children

Name of Researchers and School/Faculty: Liezel Hurter, Dr. Lynne Boddy, Dr. Zoe Knowles (Research Institute for Sport and Exercise Sciences), Dr. Lorna Porcellato (Public Health Institute)

Please answer the following questions on behalf of your child:

Name………………………………………………………….

Gender…………………………………………………………
Date of Birth ………………………………………………….
Home post code ……………………………………………

Child's Ethnicity		***(✓)***
White	English/Welsh/Scottish/Northern Irish/British	
	Irish	
	Gypsy or Irish Traveller	
	Any other white background:___________________________	
Mixed/Multiple Ethic Group	White or Black Caribbean	
	White and Black African	
	White or Asian	
	Any other mixed/multiple ethnic background: ____	
Asian/Asian British	Indian	
	Pakistani	
	Bangladeshi	
	Chinese	
	Any other Asian background: ____	
Black / African / Caribbean / Black British	African	
	Caribbean	
	Any other Black/African/Caribbean background: ____	
Other Ethnic Group	Arab	
	Any other ethnic group:____	

This information will be used when describing the group of participants involved in this study, and to look at whether any differences between groups exist. If you do not give your permission for this type of analysis, please leave the information blank.

APPENDIX F: Study 4 – Participant information sheet

LIVERPOOL JOHN MOORES UNIVERSITY

Participant Information Sheet for Parents

LJMU's Research Ethics Committee Approval Reference: 18/SPS/030

Title of Study: Parental perceptions on children's sedentary behaviours.

School/Faculty: Sport and Exercise Sciences

Name and Contact Details and status of the Principal Investigator:
Liezel Hurter (PhD candidate)
Email address: L.hurter@2016.ljmu.ac.uk
Telephone: 077 097 09630

Name and Contact Details of the Investigators:
Dr. Lynne Boddy – L.m.boddy@ljmu.ac.uk ; 0151 231 4275
Prof. Zoe Knowles – z.r.knowles@ljmu.ac.uk
Dr Lorna Porcellato – l.a.porcellato@ljmu.ac.uk

You are being invited to take part in a research study. Before you decide it is important for you to understand why the study is being done and what participation will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

1. What is the purpose of the study?

My research focus is children's sedentary behaviours. We know that physical activity is good for our health, but we also know that many children spend a lot of time in sedentary behaviours like watching television, playing video games etc. Your child participated in my previous study, where I measured 75 children's sedentary behaviours. The purpose of this study is to get a better understanding of parents' views and beliefs about children's sedentary behaviours. This will help us to identify factors influencing children's sedentary behaviours and your insights will help to shape future projects aiming to reduce sedentary behaviours.

2. **Why have I been invited to participate?**

You have been invited, because your child participated in my previous study and you ticked the box “I am interested to receive information about the follow-up study regarding my own views on children’s sedentary behaviours” in the previous consent form.

3. **Do I have to take part?**

No. It is up to you to decide whether or not to take part. If you do decide to take part you will be asked to complete a short online survey, giving your consent to be interviewed via email. You can withdraw at any time by informing the investigators without giving a reason for doing so.

4. **What will happen to me if I take part?**

First, you will be asked to complete a short, online survey. The survey will ask you 10 short questions, about you and your family. I use this information to describe the sample of participants. I will remove your name from your answers, and replace it with a code, so all your answers will be anonymised. If you have any questions, you are welcome to ask them before you complete the survey.

Then the interview process will start. This interview will not follow the traditional method of conducting an interview; it will be done via email. I will send you three to four interview questions at a time, and you will respond with your answers via email. These questions will be open-ended allowing you to provide as much information as possible. The questions will cover topics like your views on children’s screen-time, physical activity, how you think we can help children become more active etc. You can answer the questions on your own time. There are no right or wrong answers; it is your opinion that we are interested in. The interview will last for about five emails back and forth. If you so wish, I will send you your child’s results from the previous study. If you have any questions about his/her results, you are more than welcome to ask.

This email method has primarily been chosen to allow you more time to respond to the questions at a comfortable pace for you. The email address you will send your responses to will be the researcher’s secure university email.

5. **What are the possible disadvantages and risks of taking part?**

Discussing our children can sometimes be a sensitive subject and participants might feel apprehensive about how their child’s results reflects on them as parents. I have four children of my own, all in primary school and my eldest was also a participant in the previous study. I believe I understand and experience the daily challenges of parenting, so I am not here to judge you! Remember that your answers will be anonymised, but if anything makes you uncomfortable, you do not have to answer the question.

6. **What are the possible benefits of taking part?**

There are no direct benefits to you for taking part in the study, though if you choose to we can feed back your child’s results from the previous study.

7. **What will happen to the data provided and how will my taking part in this project be kept confidential?**

   All the responses and information you provide will be copied into a password protected Word document on a password protected computer with a code (not your name) and the email thread will then be deleted. The link from the code to your identity will be stored securely and separately from the coded data. We might use direct quotes from your answers in future publications, but such quotes will always have a code and not your name attached. The email account you will be sending your response to is a secure domain. It is important to consider that the email account you use may not be a secure domain. You are free to withdraw from the interview process at any point and your responses will not be used. I ask that you inform me if you do wish to withdraw so your data is not used.

   Personal data will be stored confidentially for 5 years and will be accessible only to the research team.

8. **What will happen to the results of the research project?**

   The researcher intends to publish the results from this study in a PhD thesis as well as a journal article.

9. **Who has reviewed this study?**

   This study has been reviewed by, and received ethics clearance through, the Liverpool John Moores University Research Ethics Committee (Reference number: 18/SPS/030).

10. **Limits to confidentiality.**

    Please note that you are responsible for your own inbox, and that the email thread might be automatically saved at your end (depending on your service provider).

11. **Data Protection Notice**

    The data controller for this study will be Liverpool John Moores University (LJMU). The LJMU Data Protection Office provides oversight of LJMU activities involving the processing of personal data, and can be contacted at secretariat@ljmu.ac.uk. This means that we are responsible for looking after your information and using it properly. LJMU's Data Protection Officer can also be contacted at secretariat@ljmu.ac.uk**.** The University will process your personal data for the purpose of research. Research is a task that we perform in the public interest.

    Your rights to access, change or move your information are limited, as we need to manage your information in specific ways in order for the research to be reliable and accurate. If you withdraw from the study, we will keep the information about you that we have already obtained.
    You can find out more about how we use your information by contacting secretariat@ljmu.ac.uk.

    If you are concerned about how your personal data is being processed, please contact LJMU in the first instance at secretariat@ljmu.ac.uk. If you remain unsatisfied, you may wish to contact the Information Commissioner's Office (ICO). Contact details, and details of data subject rights, are available on the ICO websiteat: https://ico.org.uk/for-organisations/data-protection-reform/overview-of-the-gdpr/individuals-rights/

11. Contact for further information

Liezel Hurter – Lhurter@2016.ljmu.ac.uk

Thank you for reading this information sheet and for considering taking part in this study.

APPENDIX G: Study 4 – Questions in online survey

1. I have read the information sheet and am happy to participate. I understand that by completing this online survey I am consenting to be part of the research study and for my data to be used as described.

   YES / NO

2. I agree to take part in the interview via email. I understand that parts of my answers might be used verbatim in future publications, but that such quotes will always be anonymised.

   YES / NO

3. Please choose the right answer: I am a

   Mom / Dad / primary carer

4. Your ethnicity:

   White (English/Welsh/Scottish/Northern Irish/British)
   White (Other)
   Mixed / multiple ethnic groups
   Asian / Asian British
   Black (African)
   Black (Caribbean or other)
   Other ethnic group
   If other, please specify:
   [Insert text box]

5. How many adults live in your house?

   1 / 2 / 3 / 4 / 5

6. How many adults with parental responsibility live in your house?

   1 / 2 / 3 / 4 / 5

7. Your education: I went to

   High school / College / University / Other
   If other please specify:
   [Insert text box]

8. Your home: Do your child/children have access to a garden or backyard?

   YES / NO

9. We want to focus on your Year 6 child, but can you tell us who else lives in the household? Does your child have any brothers or sisters and how old are they?

   [Insert text box]

10. Please state the name of your child who took part in our previous study while he/she was in Year 5.

   [Insert text box]

APPENDIX H – Study 4 Interview guide

Research Question	Possible Interview questions	Prompts / follow-ups	Email
Are parents aware of the risks of too much sedentary behaviour?	• How much time do you think your Year 5 child spends in sedentary activities per day? • What type of sedentary activities does your child take part in outside of school? • What are the risks of spending too much time sedentary? • Is your child's sedentary behaviours something that worries you and why or why not? • How important is increasing physical activity among your family to you? What do you do (if anything) to increase your family's physical activity?	Why / why not?	1
Is screen time an influencing factor?	• Do you sometimes feel you are competing with technology (screen time) to get your child's attention? • What factors do you feel compete with your chances to be more active as a family? • Do you have specific rules in your family with regards to screen time? What are they?	Please expand.	2
What are the familial or contextual factors influencing children's sedentary time?	• Below is a table with factors that a group of researchers in this field have come up with. Can you please highlight the ones that you think might have an influence on your child's sedentary time? • Do you see a difference in your child's sedentary behaviour and physical activity during winter vs summer time? • How do you feel about your neighbourhood in terms of opportunities to be active?	Could you please rank those factors you highlighted? Just the first 1 to 5?	3
What take-home messages are there for future interventions?	• In an ideal world, what do you think needs to change for children to become more active and less sedentary? • Do you have any suggestions that you feel might help us design an effective intervention programme?		4
The fifth email would most likely include a few follow-up questions arising from previous responses. It will also contain a summary of his/her child's results from the previous study.			5

APPENDIX I: Studies 1 to 4 – Ethical approval certificates