The measurement, levels, and correlates of physical activity in a bi-ethnic population of young children

by

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A Doctoral Thesis

Submitted in partial fulfilment of the requirements for the award of

Doctor of Philosophy of Loughborough University

September 2016

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Abstract

Background: The first five years of life, called the early years is a period of rapid and vital physical, behavioural, emotional and social development. Physical activity (PA) is one of the behaviours which develop during the early years, and high levels of PA during the early years have been shown to be related to multiple health outcomes. The importance of PA of young children (children during the early years) has been highlighted by a number of national governments. In order to better inform future interventions and public health policies, a greater understanding of the correlates and determinants of young children's PA is vital. Previous research has been limited through measurement inconsistencies, and few studies have been conducted within multi-ethnic communities, where many young children in the United Kingdom are born.

Thesis Aims: 1) to systematically review published research in order to establish currently known correlates and determinants of PA in the early years and identify gaps within the literature. **2)** Calculate an accelerometer wear-time criteria to reliably measure young children's habitual PA. **3)** Investigate the validity and test re-test reliability of a new parental proxy reported PA questionnaire. **4)** Investigate the levels and correlates of moderate-to-vigorous PA (MVPA) in toddlers (1-3 year olds) from a predominately bi-ethnic and bi-linguistic population.

Methods: Aim 1) nine electronic databases were searched to identify previous research which investigated associations between an exposure/variable, and a quantitative measure of PA. Correlates/determinants of total PA (TPA), MVPA and light-intensity PA (LPA) were reported using an ecologic model. **Aim 2)** to calculate a wear-time criteria for young children a simple stepped process was used whereby statistical tests were run to determine the minimum length of wear for one day, if there were any differences between weekdays and weekend days, and the presence of reactivity. Intra-class correlation models and the Spearman-Brown prophecy

formula were used to calculate wear-time reliability. **Aim 3)** this study was undertaken by 196 parents completing a proxy report questionnaire on their child's PA and sedentary behaviour after seven days of their young child (mean age 3.2 ,SD: 0.8 years) wearing an accelerometer. A total of 156 (79.6%) questionnaires were completed in English and 40 (20.4%) were completed in transliterated Urdu. Of the 196 parents, 109 parents completed the EY-PAQ a second time seven days apart from the first EY-PAQ completion; this was to assess test re-test reliability of MVPA and sedentary time. Validity analysis used all data and data falling with specific proportion boundaries for MVPA (2%-41%) and sedentary time (30%-94%). Reliability was assessed using intra-class correlations (ICC) and validity by Bland–Altman plots and rank correlation coefficients. **Aim 4)** this study was undertaken by conducting a cross-sectional analysis using 24 month olds and their mothers data collected as part of the Born in Bradford (BiB) birth cohort sub-sample study called BiB1000. The outcome variable was daily minutes of MVPA measured by the EY-PAQ. Numerous independent variables covering the layers of an ecological model were selected. Univariate linear regression models accounting for sex, age, language and season were conducted to examine the differences between White British and South Asian children's daily minutes of MVPA and each of the EY-PAQ's domains, and the proportion of time spent in MVPA within each of the EY-PAQ's domains. A series of univariate linear regression analyses were performed to examine and identify correlates of MVPA (for the whole sample, and separately for White British and South Asian children). Significant variables found in univariate analyses were then included in hierarchical multivariable regression models (based upon the ecological model), in order to examine the percentage of variance accounted for in daily minutes of MVPA.

Results: Aim 1) The systematic review identified a large volume of published research. All studies took place in high income countries and few studies (6%) were of high quality. A small number of correlates and determinants of TPA were identified. The only correlate of MVPA was sex and no determinants of MVPA or LPA were found. PA correlates/ determinants were relatively consistent between objective and subjective PA measures and few studies investigated correlates of toddlers or between children with White and South Asian ethnicity. **Aim 2)** No differences in accelerometer-determined time in TPA, MVPA or sedentary time were observed between weekdays and weekend days within this sample of young children. Similarly, there was no evidence of reactivity to accelerometer use. For young children living in Bradford, an accelerometer wear-time of a minimum of six hours on any three days was shown to provide reliable estimates of accelerometer-determined time in TPA, MVPA, and sedentary time. **Aim 3)** The test re-test reliability of the EY-PAQ was moderate for sedentary time and fair for MVPA. The EY-PAQ had poor agreement with accelerometry with both sedentary time and MVPA before the application of boundaries. Post application of boundaries the EY-PAQ still had poor agreement with accelerometer-determined sedentary time but good agreement for MVPA. Limits of agreement were wide for all variables and language and ethnicity did not confound results. **Aim 4)** Bradford toddlers were found to be very active and no difference was observed between proxy-reported time spent in MVPA between White British and South Asian children. However, White British toddlers were found to have spent significantly more time in reported MVPA while walking for transport compared to South Asian toddlers; while South Asian toddlers reportedly spent significantly more time of MVPA in the home compared to White British toddlers. Correlate models were only statistically significant when multi-layers of the ecological model were included; and correlates differed for South Asian and White British children.

Conclusions: There is a need for more high-quality studies exploring correlates/determinants across all layers of the ecologic model, and research investigating MVPA correlates/determinants of toddlers and between ethnicities is sparse. The work reported within this thesis has produced a reliable wear-time criterion for use to estimate accelerometer-determined PA and sedentary time in young children living in a bi-ethnic community. This criterion can now be used in future accelerometer studies (validation, observational and intervention) and the stepped-process offers researchers a method to derive sample-specific wear time criteria. The EY-PAQ is a promising habitual population-level measure of young children's MVPA from a bi-ethnic community. In situations when objective methods are not possible for measurement of young children's MVPA, the EY-PAQ may be a suitable alternative. Levels of toddlers MVPA did not differ by ethnicity but the contexts and correlates did. Therefore, future interventions should seek to maintain and maximise high levels of toddlers MVPA and tailor interventions by ethnicity. The research conducted within this thesis will inform the development of surveillance systems, interventions and public health polices to improve young children's PA levels, particularly children living in a bi-ethnic community.

Acknowledgments

I would first like to acknowledge my two supervisors Dr Sally Barber and Dr Stacy Clemes. Thank you very much to both of you for the wonderful opportunity and for the constant and unbreakable belief in me throughout this whole process, and for being two of the nicest people I have ever met.

Thank you to Professor John Wright and Dr Rosie McEachan for allowing me to become a member of the Born in Bradford family; and thank you to all the members of the Born in Bradford team who I have worked with over the years. There are too many people to individually thank and list here but to name a few, thank you – Shaheen Akhtar, Ann Barratt, Iram Fayyaz, Lynn McVey, Hanan Ahmed, Dr Liz Andrews, Dagmar Waiblinger, Laura Lamming, Rihab Kazi, Julia Blackburn, Samina Janjua, Sammera Ali and Zille Rabab.

This thesis would not have been possible without the aid of my 'unofficial supervisors' and dear friends Dr Paul Collings and Dr Silvia Costa. These two outstanding scientists and all round decent individuals went out of their way to offer their time, support, encouragement and advice. I will never forget, thank you.

I send my gratitude to Dr Lauren Sherar for offering words of wisdom as my internal annual reviewer; and to Dr Ash Routen, Dr Helen Moore, Dr Trina Hinkley, Dr Katy Shire, Professor Paula Griffiths and Gillian Santorelli, who have all contributed significantly to the studies presented in this thesis as co-authors of the resulting published work – it has been a pleasure working with you all.

I currently have the honour of sharing an office with some wonderful people, who have all extensively encouraged and supported me through the difficult final steps of completing this thesis, so thank you Dr Nimarta Dharni, Dr Sara Ahern and Dr

Noortje Uphoff for giving me such sincere support in the final months. A few passing nice words really do go a long way and mean a lot.

My biggest thank you goes to the staff of Bradford schools and children centres, and of course to Bradford children and their families, who all gave up their time to participate in the studies which data of the thesis came from. A special acknowledgement is warranted for Bradford mums for who without, Born in Bradford would not exist and neither would this thesis. And of course for welcoming me into their homes and for the many "brews" I have enjoyed over the last few years.

On a personal note, thank you to my own family for their unconquerable faith and love. On an emotional level I send my most loving gratitude to my own mum, Elaine May. There truly is no love greater than what a mother has for her children; late nights, early mornings, good days, bad days, indifferent days, my mum is always there forever being my biggest fan. Without that love and support I would never have dreamt of pursing a PhD and without a doubt would of never of completed this thesis – thank you mum!

Finally, I sincerely acknowledge and dedicate this thesis to Susan Bingham, who sadly died in 2008. She was such a wonderful and kind person, who I was very fortunate to have known and even more fortunate to of had as my grandma. Without her encouragement I would have never of applied or dreamt of going to university, never mind continue to pursue a doctoral degree and a career in academia.

Thank you all again.

Daniel ☺

Publications

Published work arising from this thesis

Bingham DD, Costa S, Hinkley T, Shire KA, Clemes SA, Barber SE. Physical activity during the early years: a systematic review of correlates and determinants. *American Journal of Preventive Medicine*, 2016;51(3):384–402.

Bingham DD, Costa S, Clemes SA, Routen AC, Moore HJ, Barber SE. Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years - a worked example following a stepped approach. *Journal of Sports Sciences*. 2016:1-6.

Bingham DD, Collings PJ, Clemes SA, Costa S, Santorelli G, Griffiths P, Barber SE. Reliability and validity of the early years physical activity questionnaire (EY-PAQ). *Sports*, 2016;4(2):30.

Copies of published abstracts are found in Appendix 1.

In preparation

Bingham DD, Clemes SA, Barber SE. The levels and correlates of moderate to vigorous physical activity of two year old children from a bi-ethnic population: A BiB1000 study. *Journal of Physical Activity and Health*, Summer 2017.

Conference Contributions

Bingham DD, Costa S, Hinkley T, Shire KA, Clemes SA, Barber SE. "Physical activity during the early years: a systematic review of correlates and determinants," oral presentation at the 2015 Annual Meeting of the International Society of Behavioural Nutrition and Physical Activity (ISBNPA), Edinburgh, Scotland.

Bingham DD, Clemes SA, Costa S, Santorelli G, Griffiths P, Barber SE. "Reliability and validity of the early years physical activity questionnaire (EY-PAQ)," poster presentation at the 2015 Annual Meeting of the International Society of Behavioural Nutrition and Physical Activity (ISBNPA), Edinburgh, Scotland.

Bingham DD. "Mini movers and their mum: levels and correlates of physical activity," oral presentation at the 2015 Born in Bradford Scientific Conference, Bradford, England.

Bingham DD. "Physical activity and sedentary behaviour in the early years," oral presentation at the 2013 Born in Bradford Scientific Conference, Bradford, England.

Bingham DD, Costa S, Clemes SA, Akhtar S, Wright J, Barber SE. "Differences n 3-4 year olds children's physical activity levels following application of different accelerometer cut-points," poster presentation at the 2013 Annual Meeting of the International Society of Behavioural Nutrition and Physical Activity (ISBNPA), Ghent, Belgium.

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Abbreviations

AEE – Activity energy expenditure

BIB – Born in Bradford

BMI – Body Mass Index

CARS – Children's Activity Rating Scale

CHD – Coronary heart disease

CI – Confidence interval

CPAF - Children's Physical Activity Form

C-PAQ – Childrens Physical Activity Questionnaire

CPM – Counts per minute

CVD – Cardiovascular disease

CVD – Cardiovascular disease

DLW – Doubly labelled water

EE – Energy expenditure

EY-PAQ – Early Years Physical Activity Questionnaire

HR – Heart rate

LPA – Light physical activity

LVPA – Light to vigorous physical activity

MET –Metabolic equivalent

MPA – Moderate physical activity

NHS – National Health Service

PA – Physical activity

PAEE – Physical activity energy expenditure

Pre-PAQ – Preschool-age physical activity questionnaire

RCT – Randomised control trial

SA – South Asian

SB – Sedentary behaviour

SES – Socio-economic status

ST – sedentary time

TPA – Total physical activity

VPA – Vigorous physical activity

WB – White British

WHO – World Health Organisation

CHAPTER 1 - Introduction

1.i. Preface

The literature review presented in this chapter presents the premise for the thesis along with outlining the key concepts of physical activity. The chapter is split into two parts. Part one covers the definitions, the historical perspective and describes current physical activity research in young children. Part two reviews the literature regarding the measurement of physical activity in young children.

1.1 PART ONE – physical activity and health in the early years

1.1.1. What is physical activity? Definitions, dimensions and domains

Physical activity (PA) defined as 'any bodily movement produced by skeletal muscles that results in energy expenditure'[1-3], is a complex behaviour.[3] Part of the complexity is due to the term PA widely being used interchangeably with physical fitness and exercise, within scientific literature and wider societal use. Physical fitness which is not synonymous with PA, is defined as the 'set of attributes that people have or achieve that relates to the ability to perform PA.'[3] These attributes can include skill related components (agility, balance, co-ordination, power, reaction time and speed)[3], and also health related components (body composition, cardiorespiratory endurance, flexibility, muscular endurance and muscular strength).[3] Exercise is a domain of PA which is defined as 'planned, structured and repetitive bodily movement done to improve or maintain one or more components (skill or health) of physical fitness.'[3]

The broadness and complexity of PA is part because it is a behaviour with multiple dimensions; [4] each dimension can be presented and measured in different ways.[4] The specific dimension of interest is dependent upon the research question and interest.[1] Dimensions of PA are PA energy expenditure, intensity, frequency, duration and mode.[2] The PA dimension of physiological energy expenditure is energy expenditure caused solely by PA (physical activity energy expenditure [PAEE]). Physical activity energy expenditure is often calculated through estimating basic metabolic rate and subtracting this from total energy expenditure while also taking into account diet-induced thermogenesis.[2,5] The intensity of PA is the physiological exertion of undertaking PA. Physical activity intensity for adults has been generally categorised based on the metabolic equivalent (METS). Light intensity PA equates to 1.6-2.9 METS,[6-8] moderate intensity PA is 3-5.9 METS[6-8] and ≥6 METS equals vigorous intensity PA[6-8] and sedentary behaviour (SB) is defined as any waking behaviour characterized by an energy expenditure of ≤1.5 METs while in a sitting or reclining posture.[9,10] Adult METS values do not accurately define physical activity intensities of children and therefore are not appropriate to use as values for energy costs of children's activities.[11-13] The unsuitability of adult METS for categorising children's activity is because the energy cost of children's activities increases with age due to development of muscle mass and physical capability associated with growth and developmental maturation.[11,14] Physical activity level (PAL), which is the ratio of total energy expenditure to basal metabolic rate (BMR), increases from early childhood to adolescence, this is mostly because of BMR decreasing with age.[11,15] For pre-schoolers (aged 3-5) sedentary behaviours have been found to have METS values of 1.2-1.7 (sitting while watching television, colouring, playing video games and playing with toys) and moderate-to-vigorous physical activity METS have been found to be 2.8-4.7 (dancing, aerobics, walking, jogging and running).[11] The METS values are lower in pre-schoolers compared to older populations, again because of young children's higher BMRs and developmental immaturity.[11] METS values for children younger than 3 are unknown. This is because of the lack of understanding toddlers will have of being asked to perform activities at a given time and also because of low feasibility of toddlers undergoing calorimetric measures.[11] Not engaging in sufficient amounts of PA (i.e. meeting PA guidelines for health) is termed 'inactive (inactivity).'[10] The frequency of which PA takes place is the number of bouts of PA taking place during a period of time.[1] An example is the number of times an individual is moderately active during a one day period. The duration of bouts is the amount of time a single bout of PA takes place;[1] an example would be a continuous walk for 10 minutes. Finally the mode of PA is the specific type of PA taken place;[1] examples would be playing sport or engaging in active play in the house, garden or child-care/school. Physical activity can also be subdivided into different domains, which is where PA takes place.[1] Examples of PA domains are the home, school, physical education lessons, sports, school break time (recess), and habitual PA. Each of the dimensions of PA take place within the different domains. The domains and dimensions of PA explored by research will affect the choice of methods applied in order to measure specific dimensions of PA, with good levels of efficacy (see part 2).

1.1.2. Non-communicable diseases

It is well documented physical activity is positively associated with each of the aspects of health (a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity).[16] Non-communicable diseases (e.g. cancer, cardiovascular disease (CVD), chronic respiratory diseases and type II diabetes mellitus) are the most frequent cause of mortality in the majority of countries, whether low, middle or high income (apart from areas of Africa).[17] Levels of global adult inactivity (not taking part in 150 minutes of weekly MVPA) in 2010 were 23%, with a difference between high income countries (26% men, 35% women) compared to low-to-middle income countries (11% men, 26% women).[18] Because of the increasing problem of inactivity the world health organisation (WHO) declared physical inactivity to be the fourth leading cause of non-communicable diseases.[19] Lee[20] reported that of the 57 million global deaths caused by non-communicable diseases in 2008, 5.3milion (9.3%) were caused prematurely by physical inactivity. Lee[20] also concluded that if prevalence of physical inactivity was decreased between 10-25%, between 533,000 to 1.3 million premature deaths could be averted annually.

The problem of inactivity does not stop at premature mortality, it also places strains upon governments and health services, particularly economic strains. One example is in the United Kingdom where it was reported in 2007 that physical inactivity cost the National Health Service (NHS) is £0.9 billion per year.[21] The figure increased significantly when considering the role physical inactivity plays within obesity, of which is estimated to cost the NHS £2billion; and the wider economic impact costing £10billion in 2007. These figures are projected to increase to £9.7billion and £49.9billion come 2050.[21]

1.1.3. The physical activity transition model

The role physical inactivity has played in the increased prevalence of non-communicable diseases is not surprising, when considering the drastic changes of the cultural, economic and environmental structures of human society in the last few centuries.[22,23] In the last 300 years human beings, through industrialisation and technological advancement, have quickly changed the fabric of society and the everyday environment where people find themselves day to day.[23] Human beings for most of their existence have predominately been hunter-gathers; which required high levels of PA on a daily basis in order to survive. Examples of activities were seeking water, foraging and hunting food, creating shelter and escaping predators.[23] During the last 300 years cultural and environmental shifts have led to the majority of populations becoming more inactive.[22] Technological advancements have led to human physical labour being drastically reduced in agriculture, manufacturing and transportation. The need to be active in order to survive has changed to a culture of the majority having to seek and find opportunities to be active, for reasons mainly due to enjoyment or health. The physical activity transition model (see figure 1.1) outlines the factors which contribute to the transition from an active society to an inactive society, and the resulting health consequences.[23] Recent evidence supports the PA transition hypothesis in Kenya[24], and with many other low-middle income countries growing economically and acquiring more contributing factors of the PA transition model (e.g. economic growth, urbanisation), it is expected an increase of global non-communicable diseases during the middle and end of the 21st century. The challenge of decreasing inactivity and increasing PA is a primary goal in the PA epidemiology. This is through measuring PA levels of populations, identifying factors association with PA (correlates and determinants), and then using the findings to inform the design of future interventions; and thus increase the health benefits associated with PA and/or reduce the health consequences linked to inactivity.[25,26]

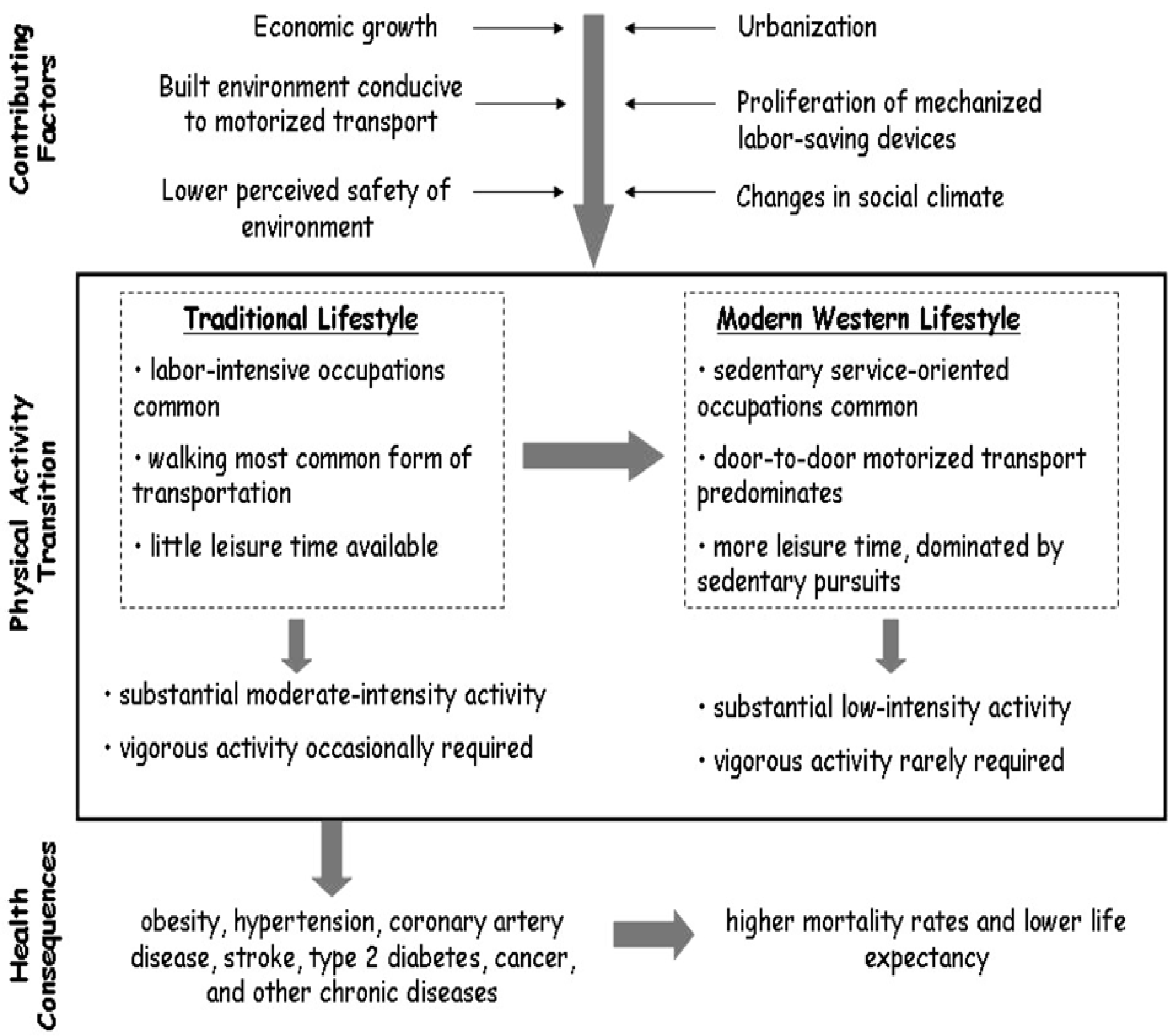

Figure 1.1: The physical activity transition model. Source: Katzmark (2009)[23]

1.1.4. The Early years

The focus of this thesis is PA during the early years. The early years, defined as the first of years life, is when significant growth and development of children occurs. The early years can be divided into three distinct age groups; infants who are 0-1 years of age, toddlers 1-3 years of age and pre-school children 3-5.[27] The Denver Developmental Screening Test[28,29] is a tool applied to measure development progression of children aged 1 month to 6 years. The test was created to identify children who are at risk of not developing sufficiently, but is also a good guide of the developmental stages children will undergo during the early years (Figure 2).[28,29] During the infant period children will begin movements of the arms and legs at around 8-9 weeks old;[30] then during the infant year children will first begin movement of the head, reach and grasp objects, roll over, sit up and eventually begin to crawl and stand. When children enter the toddler years (ages 1-3), within the first year most children will begin to walk and then begin developing the locomotor skills of running, jumping, hopping and skipping. Fine (manipulative) motor skills also begin to develop during the toddler years. When children enter the preschool years, locomotor and manipulative skills are further developed. According to Malina[30] the level of motor development and progression is dependent upon the interactions between the child themselves (biological factors; body size, proportions, body composition, maturity and cognitive abilities); the environment (stimulation, rearing atmosphere, toy to play with); and the movement task required (hip-knee-ankle action in walking, coordination in crawling). It is clear that each age group within the early years are at different stages of physical development. This means the concept of what PA is, is drastically different for infants compared to pre-schoolers. The terms 'early years' and 'young children' will be used interchangeably throughout the thesis, however both terms for the thesis refer specifically to children aged 1-5 (toddler and pre-schooler). Infant children will not be a focus for the original research presented in this thesis. A clear distinction will be made between toddlers and pre-schoolers and where possible results will be presented separately.

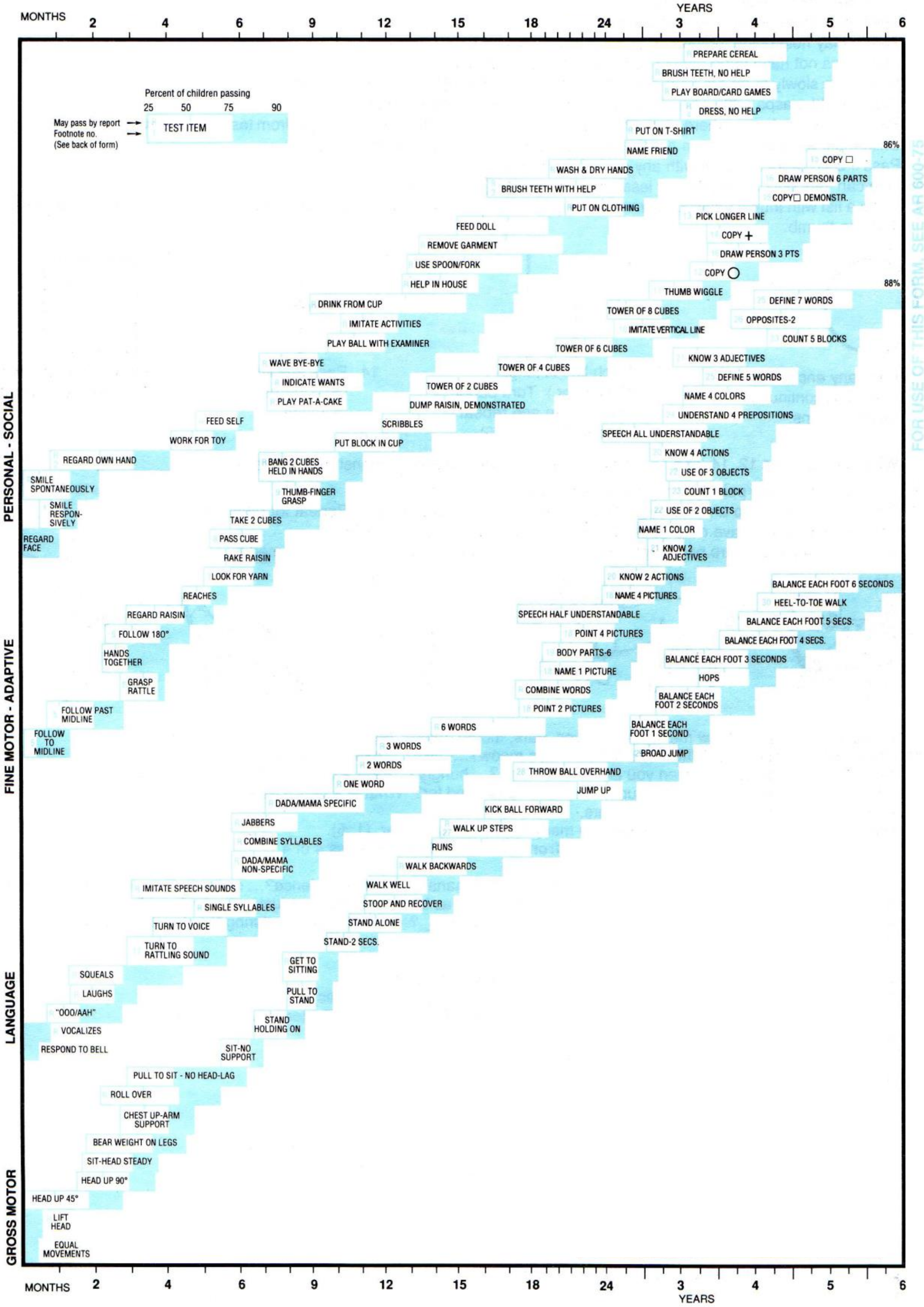

Figure 1.2: The Denvar II Development Screening test. (Sperhec et al, 1991).[28,29]

1.1.5. Health associations of physical activity during the early years

Physical activity is widely reported to have positive health effects across the whole spectrum of life.[27,31-36] Physical activity can be both a preventive and treatment means for many health outcomes (obesity, stroke, type II diabetes mellitus, coronary heart disease, and depression).[37-46] The promotion of PA during childhood aims to develop the physical, mental and social aspects of health and prevent the onset of disorders[27,38,41,47-49], particularly obesity.[38,49-53] Studies investigating the association between health outcomes and PA specifically in young children are fewer in number compared to studies within older children.[27,54] However, due to the advancement of measurement technology (see part two) the volume of PA research in young children has and is growing in the last two decades. A systematic review including only randomised control trials (RCT) or prospective designed studies (high quality) by Timmons[27], identified six areas of health associated with PA during the early years (adiposity, motor development, cardio-metabolic health, psycho-social health, bone and skeletal health and cognitive development). However, the Timmons[27] review did not include cross-sectional studies. Meaning only a small number of studies were identified and many large epidemiological studies were excluded. Presented next is a summary of the findings of Timmons[27] but also a summary of some of the key cross-sectional research in each of the six areas of health.

1.1.5.1. Adiposity

Timmons[27] identified 22 studies which investigated health outcomes associated with PA during the early years. The most frequent of outcomes investigated was adiposity (n = 11 studies). Studies focusing on infants found that the effect of PA upon adiposity was found in peripheral adiposity and not whole body fatness.[27,55] Seven studies explored adiposity and PA in pre-schoolers, four studies were RCT's and three were of prospective design. One RCT found PA had a protective effect for body mass index (BMI) increase in girls (68% less likely to increase BMI).[27,56] Findings of the prospective studies were higher levels of PA during toddler[27,57] and preschool[27,58] age was associated with lower levels of adiposity in later childhood. Overall the Timmons review reported the evidence up to 2012 was of low to moderate quality; because included studies used a mixture of PA measurement methods and a lack of consistency domains and dimensions of PA reported. The authors were unable to report what volume, intensity, type and frequency of PA was related with adiposity. Never-the-less, a link between PA during the early years and adiposity was concluded. However, research published since the Timmons[27] review has begun to investigate more specific domains and dimensions of PA via the use of more objective measures of both PA and adiposity. One example is a large cross sectional study (sample n = 398, 4 year olds) by Collings[59], who investigated the associations between objectively measured PA (LPA, MPA and VPA) and time with body composition in 4-y-old children. Body composition was measured by dual-energy X-ray absorptiometry (DXA). Collings[59] concluded VPA was the only component of PA which was associated with body composition. A total of 15 minutess of daily VPA was found to be associated with a 0.36% decrease of body fat, 1.90% decrease of trunk fat mass index and 1.90% decrease of fat mass index. However, caution must be taken regarding the results due to the cross-sectional design, therefore reverse causality may be present. Never the less, results of Collings[59] suggest the same conclusions as Timmons[27]; which is intervention during the early years is vital, but rather than focusing on overall PA an emphasis must be placed upon higher intensities of PA; in order to reduce the risk of high adiposity.

1.1.5.2. Motor development

Four studies were identified in the Timmons[27] review which investigated the associations between PA and motor development in young children. One study (RCT design) was conducted in infants and found the intervention group subjected to passive cycling for two months during the 12 months of infancy gained greater development of motor (body control balance and grasping), and adaptive (hand-eye coordination) skills compared to the control group.[27,60] Three identified RCTs[61,62] investigating the association between PA and motor-skills in pre-schoolers all concluded a significant difference in the gains of motor-development between the pre-schoolers subjected to a motor skill intervention in comparison to pre-schoolers assigned to control groups. However, it should be noted that although studies were reported to be of no serious risk of bias, inconsistency, indirectness or imprecision, studies were graded as being of low quality. A cross sectional study by Williams[63] investigated the relationship between the level of motor skill performance and participation in pre-schoolers. The study measured PA using accelerometry and found children (sample n = 198) in the highest tertile of motor skill total score spent a greater amount time in MVPA and VPA than children in the middle and lowest tertiles. This finding and the summary conclusion by Timmons[27] again adds weight to the perspective of promoting PA during the early years; along with the early years being the primary period of time fundamental movement skills (key motor skills) can be learned and developed.[64] Examples of fundamental movement skills are stability (balance), object control skills (catch and throw) and locomotor skills (jump, hop and skip).[64] Engaging in large amounts of PA is suggested by Timmons[27] to help develop motor skills; however, it has also been suggested that children with low competent levels of movement skills will not seek opportunities to be active and will more likely withdraw from PA, thus leading to greater risk of health outcomes linked to inactivity.[65]

1.1.5.3. Cardio-metabolic health

Three studies identified by Timmons[27] examined the effect of PA upon cardio-metabolic indicators in preschool children. One study found no significant associations.[66] The other two studies did find significant associations. The first study by Saakslahti and colleagues[67] used a parent-proxy report to measure PA and found relationships between PA and cardio-metabolic indictors were different for boys and girls. Highly active girls had a reduction of total cholesterol and highly active boys had reductions in triglycerides. This difference between sexes was also concluded by Puhl[68] who found boys with at least 56 minutes of daily MVPA measured by accelerometry resulted in having greater metabolic status. The relationship was also nearing statistical significance for girls, who participated in 46 minutes of daily MVPA ($p = 0.06$).

1.1.5.4. Psycho-social health

Timmons identified two studies which investigated the association between PA and psycho-social health, one of which was of high quality[69] and one of low.[70] Griffiths[69] found pre-schoolers taking part in a dance program as part of an RCT made significant improvements in externalization behaviour (challenging behaviour) and social competence. Buss[70] in a prospective study found teachers rated the most active children as being 'more outgoing' and 'less socially withdrawn'. More recently a systematic review investigating specifically the associations between young children's psychosocial well-being and PA has been published (2014).[54] Hinkley[54] included not just studies with control groups but also cross-sectional studies within the review; this was in order to capture the epidemiological evidence of this growing area of research. The review only included studies which used a direct measure of PA, therefore indirect measures of PA such as parents reporting on fidgeting were excluded. A total of six observational studies were identified. Results indicated the psycho-social well-being outcomes found to be positively associated with PA were young children's conduct problems, emotional symptoms, hyperactivity/inattention and peer relationship problems. [54] However, the level of evidence for studies was weak to moderate, and authors make it clear that no clear conclusions could be made via the current level (quantity and quality) of evidence.[54]

1.1.5.5. Bone and skeletal health

One RCT reported by Timmons[27] examined the relationship between PA and skeletal health in pre-schoolers. The RCT involved delivering a gross-motor activity intervention which was found to increase PA which was associated with an increase in the tibia circumference post-intervention[71] and at 12 months follow up.[72] However, there was no effect on the total body bone mineral content or the leg or arm bone areas.[71,72] A study not included in the Timmons[27] review theorised PA as having a lasting positive effects upon the skeletal system of children.[73] One such study supporting this idea, derived from the Iowa Bone Health cohort, found that five year old children in the top quartile for MVPA had significantly greater bone mineral content at 8 and 11 years.[74] More recent research by Herrmann[75], who investigated the effects of objectively measured PA on bone stiffness index, concluded an increase in 10 minutes of MVPA of preschool children led to an increase of between 1-2% of bone stiffness, which is significant for bone development. Evidence, although small in the number of studies, currently points to the short and medium term beneficial effect of PA upon bone and skeletal health of children during the early years.

1.1.5.6. Cognitive development

Only one study was identified within the Timmons[27] review which investigated the relationship between PA and cognitive development; of which the studies sample consisted of infant aged children.[60] It was found passive cycling for two months during the first 12 months of life increased language development (facial expression, sounds, vocalizations and babble), however the ultimate grading of this study was of low quality. No studies which have investigated the health effects of PA specifically during the toddler and preschool years since 2011 (date of included studies in the Timmons review) could be identified. However, two studies within childhood (4-18 years), one a meta-analysis' and the other a literature review both support the positive effects high amounts of PA participation has in relation to different aspects of cognition.[76,77] The meta-analysis by Sibley[76] reported an overall moderate (r=0.32) significant positive relationship between PA and cognitive function in both healthy children (aged 4–18 years) and children with physical and mental impairments. The largest effect sizes, which were moderate (0.34 - 0.49) were found for the cognitive variables of perceptual skills, developmental level/academic readiness, intelligence quotient (IQ) and other categories such as creativity, concentration, and cross-disciplinary batteries.[76] When looking for effects of PA upon cognitive variables by age, the effect sizes were greatest for middle school and young elementary age children (0.40). However, limitations of the included studies were the small number (n=9) and the lack of measurement rigor of the included studies.[76] A literature review by Tomporowski[77] reviewed studies with both experimental and observational designs. Conclusions made by the authors were that evidence was not strong enough in terms of quantity and quality to support a positive relationship between PA and intelligence. However, when reviewing more specific domains of cognition children with greater levels of fitness were found to perform cognitive tasks significantly quicker than children with lower levels of fitness. Finally, it was found PA had no relationship with levels of academic achievement, however it was found to have no negative impact.[77] The biggest limitation of this area is the large number of cognitive measures available which are inconsistent but also lack internal validity.[76,77] Nonetheless, more research is warranted within young children.[27] This is because cognitive abilities such as to inhibit a prepotent response (executive functions; e.g. reasoning, task flexibility, problem solving and planning and executing a task) mainly develop during the early years[77]; and also it is during the early years neural tissue rapidly grows[78], meaning high levels of PA during the early years could be beneficial.[78]

1.1.5.7. Ethnicity

One research area of young children's PA which is lacking inquiry is the role of ethnicity in the PA of young children.

There are multiple important reasons to investigate ethnic differences in PA. To begin with, a large migration of people throughout the developed world has occurred throughout the 20th century and is continuing during the 21st century.[79] The movement of people has transformed and added different cultural practices within historic homogeneous communities.[80] Health behaviours of children have been suggested to be influenced by the cultural attitudes of the ethnic group they were born into[79,80], and modifiable correlates/determinants of health behaviours may not be the same for one ethnic group compared to another.[79,80] This is possibly because of different everyday cultural practices between ethnicities including family dynamics, religious beliefs, parenting practices, primary language spoken.[79,81] To add, levels of equality (health, socio-economic) in many communities differ significantly between ethnicities[82] and thus could possibly impact everyday active behaviours such as transportation, type of sport played, safety to play in the neighbourhood, opportunities to be active.[79] Two previous systematic reviews of the correlates of PA during the early years up to 2010, reported an inconclusive association between non-white ethnicities and PA.[83,84] However, the studies included in the reviews were heavily skewed investigating mainly American populations (Hispanic, Black and White American populations). None of the studies included in the reviews investigated the differences of young children's PA levels and correlates/determinants of PA between White British and South Asian populations, which make up a large ethnic mix of communities within the UK (Bradford, Birmingham, Leicester and London).[85,86] In older children studies have concluded that White British (WB) children have significantly greater levels of PA compared to South Asian (SA) peers, habitually[87-89] and during recess.[90]

Ethnic differences in PA are a concern especially as it has been observed that non-white ethnicities have a higher predisposition for chronic diseases, which high levels of PA can help prevent (type II diabetes mellitus, cardio-vascular disease and obesity).[91-100] Markers of these chronic diseases have also been observed in South Asian children during childhood[101]; and specifically at the pre-natal[102] and prepubertal periods of life.[91,92] To add, studies have strongly suggested intervention and primary prevention during the early years could be vital in reducing health disparities between ethnicities later on in life.[102-105] No known studies have investigated the variability of PA levels and correlates/determinants of PA between South Asian and White British young children. This is a primary area of interest in this thesis.

In summary, there is a small body of evidence supporting the health benefits of PA during the early years. Present day evidence is of low to moderate quality, but PA was found to clearly have no negative effects upon the health of young children.[27] Greater knowledge of the health outcomes of all young children is required but also by different demographic groups of young children (age, ethnicity, sex, socio-economic status).[27] There is also an urgent need for future studies to be statistically powered to be able to conclude an effect and for more studies using valid and reliable measures of PA (ideally objective) and health outcomes (see part two).[27] Also a greater number of studies applying experimental and longitudinal designs are required in order to distinguish the direction of causality, and to clarify the duration and types of PA in relation to specific health outcomes.[27] Although currently limited in young children, there is a great depth of evidence supporting a positive relationship between PA and health outcomes in older children and adults;[16,34] and it is logical to think the health benefits of PA do not suddenly begin once a child has grown out of the early years, as this is biologically implausible.[106]

1.1.6. The levels of young children's physical activity

Since 2011 the UK, Australia, United States of America (USA) and Canada have all produced specific PA guidelines for children during the early years.[106-108] The Canadian government have since updated guidelines in 2013.[107] The UK, Australia and Canada guidelines are identical when it comes to the volume and overall type of activity suggested, which is a minimum of 180 minutes (3 hours) of any intensity of PA (TPA) daily, which does not have to take place in one bout. The USA guidelines[109] are more multifaceted with specific guidelines for toddlers and pre-schoolers. Toddlers are recommended to engage in at least 30 minutes of structured PA and ≥60 minutes of unstructured PA per day.[109] For pre-schoolers a minimum of 120 minutes of PA with 60 minutes being structured and lead by an adult and 60 minutes being unstructured are recommended daily.[109] Toddlers are recommended to engage in at least 30 minutes of structured PA and ≥60 minutes of unstructured PA per day.[109] All four countries also have specific recommendations for infants. The Australian and UK guidelines recommend infants should be encouraged from birth to participate in PA, with floor based play within safe environments being suggested.[106,108] The Canadian guidelines very similarly recommend infants to be physically active several times daily, particularly through interactive floor-based play.[107] The USA guidelines for infants are lengthier and recommend:[109]

- Infants should interact with caregivers in daily physical activities that are dedicated to exploring movement and the environment.

- Caregivers should place infants in settings that encourage and stimulate movement experiences and active play for short periods of time several times a day.
- Infants' physical activity should promote skill development in movement.
- Infants should be placed in an environment that meets or exceeds recommended safety standards for performing large-muscle activities.
- Those in charge of infants' well-being are responsible for understanding the importance of physical activity and should promote movement skills by providing opportunities for structured and unstructured physical activity.

Government sponsored/backed health guidelines, such as physical activity guidelines, are normally developed through scientific systematic literature reviews and with the informed expertise of academics and professionals; therefore, guidelines hold integrity. This is important for public health as government health guidelines have the purpose to not only provide health guidance to members of the public and professionals (parents, care providers and early years practitioners), but can be used as bench marks for researchers measuring the prevalence of physical activity/inactivity of populations through epidemiological and surveillance studies. The current UK government physical activity guidelines for young children is of no exception.[106] This is due to the guidelines duplicating the Australian and Canadian guidelines which followed a full systematic evidence based process,[107] and the recommended 180 minutes of TPA daily is a volume of physical activity which has a found dose response to greater health outcomes for young children.[27] However, current guidelines do not include a recommended dose of MVPA for young children, or even mention MVPA. The reason for the omission of MVPA is because of the lack evidence (few studies published) supporting a dose response between young children's MVPA and health outcomes.[106,107] The omission of MVPA could at first be seen as a concern and a missed opportunity to promote higher intensities of physical activity to the general public, especially when considering physical activity guidelines for youth (5-16 years of age) are universal in recommending the promotion of MVPA daily (at least 60 minutes)[33] and the benefits of MVPA will not logically just begin when children turn five years of age. Therefore, the promotion of MVPA during the early years could be argued to be included within the next government guidelines, especially when considering the growing evidence of MVPA related to health outcomes (outlined in section 1.5). However, a caveat to this thinking is whether MVPA is developmentally inappropriate for children under the age of 4 years of age, who may not be able to physiologically perform the activities which traditionally result in MVPA, such as running and jumping, with ease. Promoting MVPA through guidelines, based on current evidence, could possibly lead to possible injury (fall) which would be a serious concern. However, issues around young children's MVPA (measurement and correlates) are unclear and more research is required, which the original studies presented in thesis will contribute to.

In the last 20 years there has been an increase in the use of objective measures such as accelerometers as tools for epidemiological research,[84,110] which is providing a clearer picture of the amount of time young children are spending in different intensities of PA. A systematic review by Hnatiuk[111] synthesised the estimates of PA intensities via objective measures (accelerometry, heart rate monitoring and direct observation) of all identified studies (n=40). Hnatiuk[111] concluded the proportion of time a day 'pre-schoolers' (defined in the study as 2-5years) spent within sedentary behaviour (SB) ranged from 34% to 94%, LPA 4% to 33% and MVPA 2% to 41%. Bornstein[112] conducted a meta-analysis which included studies reporting accelerometer derived daily PA levels of preschool children. The study identified 29 articles and reported preschool children spent 42.8 minutes of their daily time (5.5%) in MVPA. These findings are concerning for young children due to the low levels of engagement in MVPA and high levels of SB. However, the high variability between studies was explained by studies applying different cut-points when implementing objective measures. In terms of children meeting guidelines, Beets[113] conducted a cross-sectional study (n=397) using accelerometers aiming to find the number of pre-schoolers meeting USA guidelines (120 minutes of TPA daily, 120 minutes MVPA daily and 60 minutes MVPA daily). Beets[113] found between 13.5-99.5% undertook 120 minutes of TPA daily, 0-95.7% 120 minutes of MVPA daily and 0.5-99.5% of 60 minutes of MVPA daily. The high variability of the results were again attributed to the different accelerometer cut-points that studies had applied. The issues around accelerometer cut-points are explored in greater detail in section 1.2.2.6.5.

Studies measuring the levels of PA of young children in the UK, like results of previous studies mentioned,[111-113] could not clearly report the levels of PA of young children with confidence. Hesketh[114] quantified using accelerometry the levels of PA and SB of 593 British four year olds. Pre-schoolers spent 283.5 minutes in SB and 568.5 minutes in TPA, which equated to a third of time in SB and the two-thirds in TPA, with all children meeting UK PA guidelines for young children (180 minutes TPA daily). However, pre-schoolers spent most their PA time in LPA which equalled 88% of awake time (14.2 hours) and very little time in MPA (4.2%) and VPA (3.8%). These results require further investigation especially due to the unknown health benefits of LPA, and as previously discussed health benefits of MVPA are becoming clearer within young children; and for 4 year olds it could be expected for them to perform a greater proportion of their waking time within MVPA compared to 3 year olds or 2 year olds. A limitation of the study was that the comparison to guidelines was not based upon seven consecutive days, participants were included in the analysis if they had one day of data, and guidelines specify activity every day within a week.

The most recent national survey of young children's PA in England was conducted within the Health Survey for England 2012.[115] The survey included 418 young children (aged 2-4 years) and used a parental proxy questionnaire to report whether children had met UK guidelines. The findings were that 9.5% of young children had met PA guidelines; 6.5% of parents reported their pre-schooler had engaged in some activity daily (60-179 minutes daily) and 84% of parents had reported young children took part in less than 60 minutes of TPA daily.[115] These results are concerning due to the low number of young children meeting guidelines. However, the questionnaire created for young children in this age group has not been formally validated against a criterion measure. A study by Basterfield[116] did compare the findings of the parent reported children's PA questionnaire created for the Health Surveys for England, with acclererometry in sample of 6-7 year olds. Findings of the study indicated that parents significantly overestimated PA.[116] Therefore caution must be made when considering the young children's data from the survey. More information on parental-reported questionnaires are reported in section 1.2.3.2.

In summary it is unknown what exactly the current levels of PA of young children are. The reasons for such confusion are mainly due to the current lack of understanding of how best to measure young children's PA.

1.1.7. Tracking of physical activity in the early years

Although it is unclear what the exact PA levels of young children are, one aspect of great importance is whether PA levels during the early years are associated with levels of PA in later years, also termed tracking. Understanding the tracking of PA is important, because if PA during the early years tracks into later childhood, then the early years could be a vital time to promote and establish PA.

Tracking is the retaining and stability of the relative rank of behaviour within a group over time.[117,118] There have been two different meta-analyses investigating the tracking of PA from or within early childhood. Telama[119] identified 40 studies which investigated tracking across the life span (childhood to adulthood). Results found tracking of PA was significant, but the association was of low to moderate strength during all phases of life for men, and the association was weaker for women.[119] For youth Telama[119] concluded the stability of tracking was lower during the early years than during adolescence, and tracking was weaker still when examined over transitional periods, such as childhood to adolescence, adolescence to adulthood. There were a number of issues with the literature at the time of publication (2009) which led to authors adding caution to findings. One issue was the lack of adjusting variables potentially causing error and confounding such as day-to-day variability of PA and seasonal differences.[119] Another limitation was the poor reliability of PA measures and also only a small number of studies which used objective measures. A more recent study by Jones[118] specifically reviewed studies which investigated tracking of PA from the early years (≤ 5.9 years) to middle childhood (6-12 years); seven studies were identified and the median tracking coefficient was deemed moderate (0.36). All of the studies were of high quality and used objective measures. The low-moderate tracking observed[118,119] could imply there is either currently not a clear relationship between the PA levels during the early years with PA of later childhood years; or the relationship is not stable and could possibly be more amenable to intervention. The lack of clarity could also possibly be due to either the absence of tracking or the current measurement of PA is not reliable enough nor refined enough to detect the full range of tracking. The issue of tracking is a complex area of research due to the complexity of PA.[120,121] For example the intensity of PA (e.g. MVPA) of young children is different compared to the intensity of older children, so MVPA is very different for preschoolers compared to adolescents. Therefore, it is logical to wonder why PA would be strongly related between the different stages of life; when human beings are developmentally different between stages of life, and thus PA is very different between stages of life.[120,121]

In summary, although evidence is not of great quantity and issues exist around measurement of PA; the moderate levels of tracking of activity from the early years into later childhood does add weight to the importance of promoting and establishing PA during the early years. Not only will young children get short term health benefits of PA (section 1.5) but as PA tracks, young children are more likely to gain longer term benefits if they spend a substantially amount of their waking time in PA.

1.1.8. Correlates and determinants - an ecological perspective

Despite the measurement limitations of previous research outlined in previous sections, the early years are a critical period to establish health behaviours such as PA. To add strength to this rationale is previous research suggests developmental plasticity, metabolic programming and malleability of behavioural modelling all begin during the early years, thus the early years are a vital time for PA to be established.[122,123] To add, previous studies have highlighted the importance of beginning to inaugurate modifiable factors of chronic diseases (obesity and insulin resistance); of which PA is one, during the early years.[78,124,125] Therefore it is vital to understand the factors that influence PA during the early years, in order to inform future interventions.

Factors which influence a health behaviour such as PA can be categorised into two broad categories, correlates and determinants. Correlates are factors which have an association with an outcome such as PA.[126,127] Correlates do not determine causality but show an association/relationship, and are identified through cross-sectional research. Determinants are associated factors found between an independent variable and outcome variable (e.g. PA) in longitudinal studies[60] where temporal associations over time may be observed. Studying correlates and determinants of PA is important in order to identify possible at risk demographic groups and/or mediators to be targeted in future intervention studies.[60] The purpose of correlates/determinants research is to describe and understand the influence of correlates/determinants upon a chosen outcome across the life span, thus helping to inform future interventions.[126] As PA is a behaviour with huge variability, particularly individual-variability, it is expected that numerous individual correlates/determinants are influential. Therefore grouping correlates/determinants based upon theories and models are common place.[127]

Physical activity correlates/determinants research has historically taken an ecological perspective (also commonly referred to as a socio-ecological perspective) and/or used an ecological framework to inform what variables to measure within research. This work is based upon work by McLeroy[128]. McLeroy[128] constructed an ecological model (see Figure 1.3) for health promotion programs based upon the ecological theory/perspective first presented by Brofenbrenner[129]. An ecological perspective theorizes behaviours as ongoing multi-directional processes between the individual, the socio-environment and physical environment. A hypothetical example is a young child's PA may be influenced by their sex, ethnicity, body composition, motor-skill competency (inter-personal factors), whether their parents provide opportunities to be active (intra-personal factors); have siblings to play with (intra-personal), have preschool teachers with positive attitudes (institutional), live in a neighbourhood with safe playgrounds (community), and live in a society with positive PA policies (e.g. free-swimming, low crime). All of the levels of the ecological model could possibly interact with each other or partially. For example, a new government policy providing free-child preschool care with a PA priority (goals and targets to reach), could potentially filter to the parents having more positive attitudes towards PA and thus independently aiming to promote PA, or leading to parents seeking opportunities for their child to be active. If this occurred along with other parents this could create a demand for a new playground from the local authority, and thus possibly impacting the PA of the young child. This is a hypothetical example, but presents the idea that to change a complex behaviour such as PA, aiming to understand or impact only one factor is likely to be unsuccessful. An understanding of the different factors that exist and their interaction with each other is required for greater efficacy of changing health behaviours.[126,128,129]

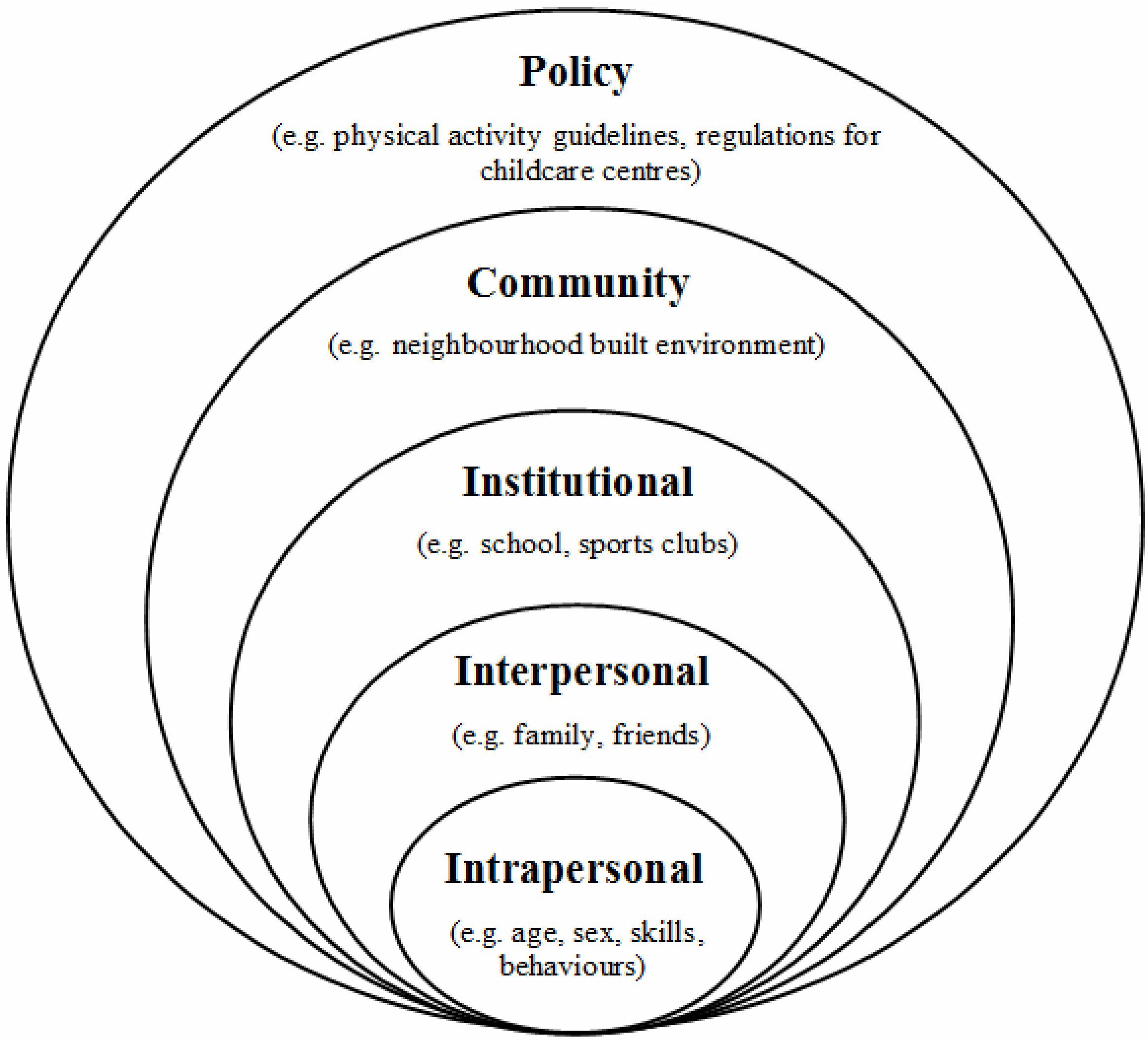

Figure 1.3: An ecological model of physical activity.

Previous systematic reviews have applied the ecological model to describe and report correlates and determinants of PA.[83,130-134] There have been two previous correlates systematic reviews[83,84] which investigated the correlates of PA specifically in children during the early years. The ecological model applied by both studies was a model first applied by Sallis[132] of which still maintained the basic premise of the model presented in Figure 1.3, but opted not to include policy, and refined the other categories into sub-categories. The levels in the model were: 1) demographic and biological (intra-personal); 2) psychological, cognitive, and emotional (intra-personal); 3) behavioural attributes and skills (intra-personal); 4) social and cultural (inter-personal and institutional), and 5) physical environment (institutional and community). In 2007 the review by Hinkley and colleagues[84] identified 39 correlates from 24 studies investigating an association between any quantitative measured variable(s) and PA. There were few keys findings (strong associations) due to the low number of studies investigating the same correlates. The factors with clear associations were sex (boys being more active than girls), age which had a strong no-association, and parents PA levels and time spent playing outdoors, which had both strong positive associations. De Craemer and colleagues[83] conducted a systematic review and identified 43 studies investigating the correlates of energy-balance behaviours of young children, of which TPA and MVPA were two such behaviours. The review applied the same criteria as that of Hinkley and colleagues[84], and only declared a factor to have a strong association or no association if four or more studies found factors to have the same direction of association. For TPA, there were no strong associations identified in either a negative or positive direction, meaning no clear correlates were recognised. No significant associations were found between sexes, age, SES, parental encouragement and availability of play equipment. For MVPA, a difference between the sexes was found, which like Hinkley et al[84] found boys to be significantly more active than girls. No strong associations were found for age and SES. Differences between the two reviews could be explained due to the different dates of which the reviews included studies. De Craemer et al[83] included studies between the years of 1990 to 2010 and Hinkley et al[84] included studies between 1980 to 2007. The two reviews also used slightly different inclusion criteria with Hinkley et al[84] including clinical factors such as wheezing, and De Craemer et al[83] not doing so. Neither of the reviews applied a quality assessment of the included studies of which could inform the strength of association of factors instead of solely relying on the ‘four or more’ criteria; also neither of the reviews reported the determinants of PA, which are supported by stronger study design than correlates. Because of differences between reviews and an expected increase of published literature since 2010[27], a new review with a broader search and inclusion criteria, reporting both correlates and determinants and applying a quality assessment, was conducted as part of this thesis and is presented in chapter 2, and has been peer-reviewed and published.[72]

1.2. PART TWO - measuring physical activity during the early years

The complexity of PA means there is currently no gold standard measure which can capture every aspect of PA (domains and dimensions).[1,2,4,135,136] Measurements of PA can be divided into two distinct groups, objective methods and subjective methods. Objective measurements record a physiological or biomechanical attribute to estimate PA or activity energy expenditure (AEE).[1,2,127] Examples of objective measurements are calorimetry, doubly labelled water, accelerometry, heart rate monitors, pedometers, direct observation and a combination of monitors. Subjective measurements are instruments which require the recalling of PA by the participant or a proxy such as a parent or teacher for a young child. Because of this nature subjective measures are more susceptible to measurement bias and error in comparison to objective measures.[1,2,127] Examples of subjective measures are questionnaires and activity diaries.

Along with reliability and validity, researchers also need to take into consideration the financial cost, feasibility and the burden placed upon researchers and participants when choosing a method to measure PA.[1,2,135-140] There is no perfect choice for researchers, and any choice is likely to involve some compromise between feasibility and accuracy (validity).[135] For example objective methods are more accurate but are also far more expensive and can have greater burden upon researchers and participants.

1.2.2 Objective Measures

1.2.2.1 Calorimetry

Calorimetry is a methodology which measures energy expenditure. There are two types: direct and indirect calorimetry. Direct calorimetry measures total energy expenditure through the direct measurement of heat produced by the body.[141] Indirect calorimetry, measures energy expenditure through calculating the amount of oxygen consumed and/or the amount of CO2 produced by the body.[142-144] Because of the high levels of reliability and validity, calorimetry has been considered as one of the gold standard criterion measures for the assessment of PA,[135,145,146] and it has been widely used to validate other PA measurement methods in young children.[68,127] However, due to the high burden placed upon the participants (enclosed in a laboratory chamber, wearing a face mask, carrying heavy equipment) the high financial cost, and the impracticality of wearing in everyday life; calorimetry is not a feasible or suitable measure of habitual energy expenditure in young children.[147,148]

1.2.2.2 Doubly labelled water

Doubly labelled water (DLW), a calorimetric method, requires participants to provide daily urine or saliva samples for a period of time between 7-14 days.[149,150] The method estimates energy expenditure through water labelled with known amounts of isotopes, which is used to calculate estimations of carbon dioxide production ((2H and 18O)).[1,2,149-151] DLW is ingested of which the deuterium is then eliminated as water, and the 18O as both water and carbon dioxide.[1] The difference found between the elimination rates is the resulting estimation of carbon dioxide production. The difference is then imputed within an equation deriving from calorimetry to estimate energy expenditure (EE).[127,141] To calculate activity EE, predicted basal metabolic rate or resting energy expenditure is subtracted from total EE. Although high levels of accuracy and considered a gold standard of activity energy expenditure, doubly labelled water is limited by the small number of participants being able to be measured within studies. Reasons for this are the high cost, high levels of training and expertise required and finally the participant burden of collecting urine and saliva samples.[146, 149, 150] A limiting factor in young children, is many young children may still wear nappies/diaper and may not yet have voluntary control of urination, therefore making the collection of urine samples difficult.[148] To add DLW provides a measure of activity EE, not intensities of PA, patterns or domains.[145,147,148] Researchers need to consider all these issues before the decision of implementing the DLW method.

1.2.2.3 Heart rate monitors

Heart rate monitors are devices which have traditionally consisted of a receiver and transmitter. A wrist worn watch displaying heart rate is most commonly used as the receiver and the transmitter as a fitted chest strap. The chest strap transmitter includes two electrodes and the receiver records heart rate at specified time intervals (e.g. 30 seconds, 60 seconds).[1,2,147] Heart monitoring has been found to be both a reliable and valid indirect objective measure of PA.[152] Due to the constant recording of data this method can be used to measure the patterns, intensities, frequency of PA[145] and has commonly been used to measure the PA of young children.[111,146,153,154]

Heart rate monitoring of PA is based upon the assumption that the relationship between heart rate and PA is linear, whereby an increase of PA will result in an increase in heart rate.[1,2,145] However, limitations of this assumption are this relationship is not robust at lower intensities (LPA) leading to a risk of error.[1,2,145,146] Also heart rate is affected by other factors independent of PA, such as body size[135], cardiorespiratory fitness[152] environmental factors (e.g. altitude and temperature)[145] and psychological stimuli.[127] Individual participant calibration techniques have been considered to overcome the short comes of heart rate monitoring, but this can be very labour intensive.[155] Other limitations of heart rate monitoring are monitors can be bulky in size and be uncomfortable for participants,[1,2] and the relationship between heart rate with energy expenditure is poor.[1,2] Strengths of heart monitoring are that it is an objective measure of PA which is able to collect data for long periods of time (≥1 week).[145,152,156] It has been found feasible, has low participant and researcher burden and is relatively inexpensive, meaning the deployment within larger studies makes this a potential method to measure population habitual PA.[145,152,156]

1.2.2.4 Pedometers

Pedometers are motion sensors consisting of spring-lever mechanisms or piezo-electric, which measures the amount of steps an individual performs over a number of different days (depending on battery life).[136,145,157] Spring-lever mechanisms comprise a spring suspended horizontal lever arm which moves up and down in response to vertical accelerations.[158] The process opens and closes an electrical circuit which records a step when the levers arm makes an electrical contact.[158] The majority of pedometer models are worn at the hip level with the aid of an elastic waist belt or a plastic clip to attach to the waist band of clothes; and contain a screen which digitally displays the number of steps recorded.[157] Some models of pedometers are used to measure distance travelled and/or energy expenditure through participants inputting additional information such as length of leg stride and body mass index.[157] However, it has been strongly suggested that these additional features are limited in their validity and only the outcome of steps should be measured by pedometers.[159]

The strengths of pedometers are they are small, easy to use for the participant, unobtrusive and the outcome unit of a step is easy for researchers to process and the general public to understand.[2] Pedometers are also cheap to purchase, maintain and replace, therefore make a very suitable measure for large population studies, of which TPA is the outcome of interest.[135,152,156] For adults the goal of 10,000 steps every day is widely cited and has been found to correspond to positive promotion of health outcomes for adults.[160,161] However, for children 10,000 steps is not enough for the promotion of health and meeting PA guidelines of 60 minutes of MVPA every day.[162] Tudor-Locke and colleagues[162] reviewed the existing literature (60 studies) and concluded 13,000 to 15,000 steps/day for boys and 11,000 to 12,000 steps/day for girls equated to meeting children's physical activity guidelines. For young children, where the physical activity recommendations are for overall activity, it has recently been found for pre-schoolers (mean age=5.0±0.8years) that just over 9,000 steps (9,099- pedometer worn on waist) equated to reaching the recommended 180 minutes of overall activity, with sensitivity being 90% and specificity 66%.[163] The findings of Vale and colleagues[163] were lower than values reported by Cardon and De Bourdeaudhuij (2007)[164] (9980 steps per day), but higher than findings by Gabel and colleagues[165] (8968 steps per day) and Pagels and colleagues[166] (7313 steps per day). Differences between studies are speculated to be because of the different instruments and methodology used (different pedometer models and wear time protocols) along with cultural and environmental differences in the daily lifestyle of preschool-aged children from different countries.[163] Nevertheless what is clear across studies is that 10,000 steps is too high a recommendation for pre-schoolers. These findings support pedometers as a promising cheap objective measure of young children's physical activity, which could be used for large surveillance studies; and also could be used by families and preschools in the future, to easily objectively measure physical activity and understand the translatable recommendation of a number of steps every day.[163]

Pedometers as with all measure do have limitations. Pedometers are unable to provide a measure of intensity of PA and are insensitive to upper body activities, cycling and water based activities[152,156], which becomes an issue of measuring young children's physical activity, especially toddlers, who are more likely to take part in activities which entail the upper body such as climbing, rolling, rough and tumble play all of which the pedometer is unable to measure.[135,138,145,157,167] Also in some age groups reactivity has been found to exist when wearing a pedometer, therefore, normal behaviours are hard to capture.[2] Despite these limitations pedometers are considered a valid and reliable measurement tool of overall PA (via number of steps performed) in most age groups[152,155,156,159] including young children (preschool age).[163-166]

1.2.2.5 Direct observation tools

`Direct observation tools' is a term applied to different instruments which generally apply a time sampling technique, by which a trained researcher(s) will observe children and document the PA that is being performed within controlled settings.[145,168] Within controlled settings direct observation has been reported as the gold standard of measuring PA.[169,170] Examples of controlled settings specifically within the early years of which direct observation tools have been used are pre-schools/nurseries, the home, playgrounds or for short periods of time for validation studies (e.g. validation and calibration of accelerometry cut-points).[171] The variables direct observation tools can measure are the intensity and type of PA along with contextual information of the environment (e.g. equipment being used), social interaction (e.g. playing with mother) or locations (e.g. outdoors).[146] Validation studies of direct observation tools have often compared direction observation with calorimetry[68] and accelerometers[131,172,173] and results of studies are promising.

Limitations of direct observation tools are the possible subjectivity of researchers/observers deciding upon the intensity of PA and also the burden upon researchers to follow individual participants for large amounts of time.[146] Another limitation is participants reacting and altering behaviours due to being observed.[145,146,174] Direct observation has much utility for the assessment of PA in controlled environments, such as during school break times, and for short term validation studies. However, it is impractical for researchers to observe participants for long periods of the day; therefore direct observation is not a suitable method for measuring habitual PA.

1.2.2.6 Accelerometry

Accelerometry is a method which has been used in a number of studies within this thesis, therefore the amount of detail explaining the different components of accelerometry is of greater detail compared to other objective measures.

Accelerometers are motion devices which have in the last 20 years have been one of the most widely used objective methods of PA (See Figure 1.4).[2,175]

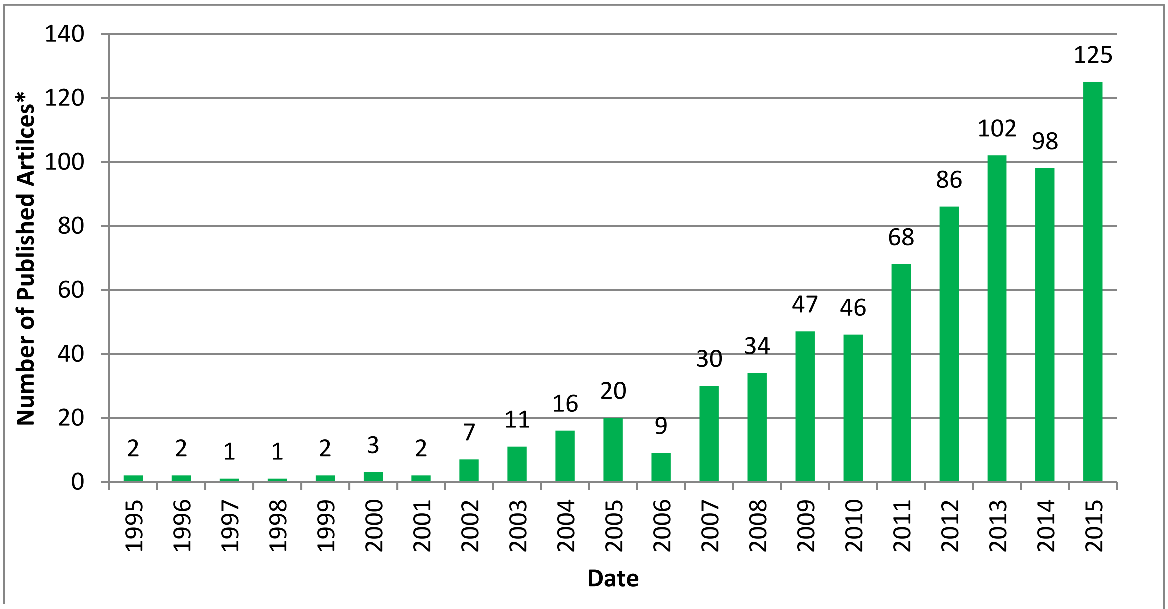

Figure 1.4: The number of articles within the Pub Med database using accelerometers from the years 1995 to 2015.
* Data generated from Pub Med database

Accelerometers are monitors which quantify body movement of human beings which is associated with PA. The specific movement measured is acceleration, which is defined as a change of velocity overtime.[176] This means accelerometers quantify the frequency, intensity and duration of body movement. Accelerometers have a long history which began in the 1960's within research examining hyperactivity, cognition and personality within pre-schoolers.[177] A long evolution occurring alongside technological advances from 1960's until the turn of the 21st century, led to accelerometers becoming one of the most favourable measures within PA epidemiology. The majority of modern day models of accelerometers measure the amplitude and frequency of acceleration via piezo-electric sensors.[178-180] Piezo-electric sensors detect acceleration in the three planes of movement (vertical, anteroposterior, and medio-lateral).[176,181,182] A piezoelectric sensor consists of a piezoelectric element and a seismic mass which are enclosed within a protective casing, that can then be worn via a strap around the waist, ankle, wrist, lower back or thigh.[181] When acceleration occurs upon the worn monitor, the seismic mass deforms the piezoelectric element. These deformations cause a displaced charge to build up upon one side of the sensor. This charge generates a voltage signal which is proportional to the applied acceleration, and thus creates a variable of acceleration.[138,176,181] This variable of acceleration occurs in one plane of movement. To measure acceleration in different planes of movement, other sensors are fitted in the required direction and the process is the same as before.[181] The acceleration data is then sampled through applying a chosen sampling frequency (i.e. average number of samples obtained in one second) which is high enough to capture all movement.[181] The majority of modern accelerometers have the choice 1-to-100 Hertz sampling frequencies.[181,182] Once data has been sampled a filtration of the sensor output occurs in order to reduce the effects of piezoelectric elements, temperature-related sensor drifts and external vibrations have upon acceleration signals.[181,182] This process results in the voltage becoming data called "raw counts."[138,181] Raw counts then go through a software processor in which different analytical approaches can be applied to convert the bidirectional (i.e. negative and positive) acceleration signals into a positive-only value of counts, which can be summarised for specified time-sampling units, named epochs.[138,176,181,182] This summarisation leads to creation of data titled counts per epoch, which is also referred to as activity counts. Activity counts are then calibrated against a chosen criterion measure (commonly direct observation in young children) to convert the dimensionless activity counts data into a meaningful data unit about either EE, sedentary behaviour or intensities of PA (LPA, MPA, VPA).[4,138] Although PA is the behaviour of interest of this thesis, due to accelerometry measuring the whole spectrum of awake energy expenditure behaviours (SB, LPA, MPA and VPA); SB is naturally discussed throughout rest of this accelerometer section.

The process of using activity-counts and then deriving meaningful data through calibration has been the standard approach of processing accelerometer data ever since the first modern accelerometers became available. However, recent new methodological techniques being developed allow the direct analysis of raw counts.[183,184] The benefit of such techniques would mean accelerometer data from different samples could be more comparable; as currently activity-counts are the universal unit of accelerometers, but are confounded by the chosen epoch lengths, and current available cut points.[112,185] But this area of research is in its infancy, therefore the use of time-sampling epochs and activity counts will continue within the chapters of this thesis which have used accelerometry (Chapters 4 and 5).

When using accelerometers to measure PA, researchers also to need make and justify important decisions.[4,176,182,185]

The decisions are:

- What type of accelerometer will be used.

- How many monitors should be used.
- Where on the body should the monitor(s) be worn (i.e. placement).
- What epoch length is the best to use.
- What are the most accurate PA intensity cut-points to use.
- How long should the accelerometer we worn for (duration of monitoring).
- How many hours of wear time is enough to be classed as a day.
- How best to classify non-wear time.

1.2.2.6.1. Types of accelerometers

There are a number of different types of accelerometers. The different types are classified by the direction of movement in which the accelerometers measure. Uniaxial accelerometers measure in one direction, the vertical plane. An example of widely used uniaxial accelerometers are the ActiGraph GT1M and 7164 models. Biaxial accelerometers measure movement in two directions, mainly in the transverse and longitudinal directions. An example of a biaxial accelerometer is the Actiwatch AW16. Triaxial accelerometers measure movement in three planes, examples of models include the ActiGraph GT3X, GT3X+, wGT3X-BT and the Stayhealthy (previously Tritrac) RT3. Omni-directional accelerometers are designed to measure in all planes of movement, however have been noted to be most sensitive within the vertical direction.[2] An examples of an omni-directional accelerometers are the Actical monitors. All examples have been widely used within children.[186]

The creation of triaxial and omni-directional accelerometers has hypothetically created an opportunity to increase measurement accuracy of young children's PA. This is due to monitors theoretically being able to measure the wide range of movements that young children engage in while being active (e.g. swinging, climbing, rolling, jumping).[185,187] However, a body of research exploring the measurement difference between monitors has yet to find any advantage of using a triaxial accelerometer over a uniaxial accelerometer.[185,186,188] However, the little difference between the two types of monitors could be explained by the placement of accelerometers.[185] If the accelerometers are placed around the waist then the dominance of movement within the vertical plane means it is obvious why there would be little difference between the two monitors, therefore currently the best choice of accelerometer to measure young children's habitual PA is a uniaxial monitor. Not only is this because of little differences with triaxial monitors, it is also due to young children's PA cut-points being calibrated using uniaxial accelerometers.[182]

1.2.2.6.2. Placement

The common accelerometer placement area is around the waist (anterior to the iliac crest).[127] The reasons for this are due to the majority of accelerometers being uniaxial, and thus are limited to a placement which will measure activity within the vertical plane. The waist/hip is logical due to being as near to the bodies' centre of mass and thus can capture the majority of habitual PA which is dominated by movements such as walking, running, skipping etc which all take place within the vertical plane.[189] The decision of placement site should be based upon the weighing up of advantages of accuracy and feasibility. It has been suggested for young children a hip mounted accelerometer is best practice to measure habitual PA,[190] but there is a need to look into possible alternative placement areas especially for infants while they are crawling.[185]

1.2.2.6.3. Number of monitors

Measuring PA in young children using one accelerometer placed upon the hip although commonly used, still has the issues around young children's sporadic multiple plane movement, which one monitor may not measure. One way to hypothetically improve accuracy would to be ask participants to wear a number of different monitors at one time.[191] In young children there is very limited amounts of research exploring the accuracy of multiple-devices.[188,191] Recent studies within a multi-ethnic population has shown only 33.7%[184] of children had complied with the eight day protocol wearing one device (hip) and between 69-75% wore the monitors long enough (see section 1.2.2.6.6) to be included in an analysis of habitual PA.[184,192] This means some young children struggle with compliance with one device. Therefore, it must be noted wearing multiple devices will increase participant burden, and researchers need to consider if the increase of burden and possible decrease in compliance is worth the increase of possible PA accuracy. More research is required to assess the possible increase of accuracy with wearing multiple devices in young children.

1.2.2.6.4. Epoch length

Epoch length as previously mentioned is the length of time raw acceleration data is averaged and summarised. Modern accelerometers are able to collect raw data so that researchers can decide upon epoch length post data collection. [136,175] Although techniques are being developed to analyse raw-data values, these methods are not established leading to researchers still deciding upon what epoch length to choose. Epoch lengths are dependent upon the individual model of accelerometer and can last one second to several minutes.[136,186,193] In respect to children, studies have reported pre-pubertal childrens PA bouts lasting between three to 22 seconds, with 96% of these bouts lasting less than 10 seconds.[4,194] This result along with young children's sporadic and intermittent PA behaviour, shorter epoch lengths of 15 seconds or less are recommended.[1,185,186] Longer epochs increase the risk of masking short bouts of MVPA as LPA, simply because the short bout is within mean average calculation. An example would be a 5 second bout of MVPA will be a higher value when comparing it between a 15 second to a 60 second epoch. One study previously examined the effects of epoch length (5 seconds v 10 seconds v 15 seconds) in comparison to direct observation estimating 2-3 year olds habitual SB, LPA and MVPA. The study found both 10 seconds and 15 second epoch lengths significantly overestimated LPA and underestimated SB and MVPA, in comparison to 5 second epochs.[182] Therefore, 5 seconds are the recommended epoch length when using accelerometers to measure habitual PA in young children.

1.2.2.6.5. Intensity classification: cut-points

In order to classify the activity counts (counts per minutes) into meaningful values, such as minutes of time within PA intensities, threshold values also known as cut-points must be applied. Cut-points are developed and calibrated through statistically comparing the data outputs of both accelerometers and a criterion measure (e.g. direct observation or indirect calorimetry), in a controlled environment such as the laboratory or childcare setting.[127,136,170,195] Calibrated cut-points are then compared to a separate sample of the chosen age group in order to assess validity. The choice of cut-points for study samples is a very important decision for researchers to consider. This is because the choice of cut-point determines the level of PA, and choosing an inappropriate cut-point could lead to inaccurate statements of levels of PA, meeting guidelines, and possibly effecting the association of PA between health outcomes or factors associated (correlates/determinants).[112,113,196]

For young children there are currently several sets of different cut-points calibrated and validated (or widely used) (Table 1.1).[152,155,156,159,169,170,188,197,198] In Table 1.1 each of the cut-points available are presented along with the details of each of the calibration and validation studies. One of the few consistent aspects of the studies is that all cut-points were calibrated and validated while accelerometers were being worn around the hip. All studies but one applied 15 second epochs. Costa[188] cut-points were calibrated using 5 seconds epoch. Two studies calibrated cut-points using triaxial (vector magnitude) accelerometers[152,188], the rest used uniaxial. All the cut-points in Table 1 have been rounded up to the equivalent of 60 sec epochs in order to compare cut-points across one minute, and also present the drastic differences between them. Sedentary behaviour (time) ranges from

≤60counts(Costa)[188] to ≤1488counts(van Cauwenberghe).[199] Moderate to vigorous PA cut-points, ranges from ≥1673counts(Trost)[170] to ≥6112counts(Costa-Vector Magnitude(triaxial)).[188] A study by Janssen[156] examined existing cut-points and aimed to establish consistency in the area by investigating which are the best suited to measure PA and SB in young children.[156] The study compared published cut-points at the time (all cut-points in Table 1 apart from Costa's, Butte's and Trost) with both whole room calorimetry and direct observation(CARS) in a sample of young children (4-6years). Results found that no cut-points were significantly accurate in the estimation of all waking behaviours (SB, LPA and MVPA) in young children. Instead the Evenson cutpoints[155] were the best for measuring SB and LPA (≤25 counts per 15 seconds, 26-56 counts per 15 seconds) and Pate cut-points were the most accurate for estimating MVPA (≥420 counts per 15 seconds). Therefore, Janssen[156] recommend combing both Evenson and Pate cut-points at 15 second epoch to accurately measure habitual PA and SB in children aged 4-6 years. The Trost cut-points, which were not included in the study by Janssen[156], calibrated and validated cut-points in a sample of 16-35 month old children (mean age: calibration=2.1years validation=2.3years).[170] Results indicated that all of the SB cut-points significantly overestimated SB, but the Evenson value of ≤25 counts per 15 seconds was the cut-point nearest to being non-significant. For MVPA the Trost cut-point of ≥419 counts per 15 seconds was very accurate in estimating toddlers MVPA. Being nearly the same as the Pate MVPA cut-point (≥420 counts per 15 seconds) Trost[170] recommended the cut-points of SB= ≤25 counts15sec; MVPA=≥420 counts15secs for toddlers. However, it must be noted that the classification accuracy between different cut-points has been found to be small[170,182,199]; but because of the many different choices of cut-points available, studies could possibly use two different cut-points to classify two different outcomes (e.g. MVPA and ST) leading to a possible unclear calculation of wear-time (ST + LPA + MVPA). Where this occurs in the studies of this thesis, it has been clearly noted.

Table 1.1: Description of studies investigating and calibrating Actigraph accelerometer cut-points, for early years children's sedentary and physical activity levels.

Study	**Sample**	**Model**	**Criterion**	**Calibration Epoch**	**Cut-points**		
Butte - Axis1[152]	n = 50	GT3X+	Room Calorimetry/DLW	15sec			Counts $60sec^{-1}$
2014	Country = USA				Sedentary Time		≤ 239
	Age = 4.5 years (mean)				Light PA (TotalPA)		> 239
	Boys n = 25; Girls n = 25				MVPA		≥ 4450
Butte - Vector Magnitude[152]	n = 50	GT3X+	Room Calorimetry/DLW	15sec			Counts $60sec^{-1}$
2014	Country = USA				Sedentary Time		≤ 819
	Age = 4.5 years (mean)				Light PA (TotalPA)		> 819
	Boys n = 25; Girls n = 25				MVPA		≥ 3908
Costa-Axis1 [188]	n = 26	GT3X+	Direct Observation (CARS)[153,158]	5sec		Counts $5sec^{-1}$	Counts $60sec^{-1}$
2013	Country = England				Sedentary Time	≤ 5	≤ 60
	Age = 2-4years (2.8years)				Light PA (TotalPA)	> 5	> 60
	Boys n = 13; Girls n = 13				MVPA	≥ 165	≥ 1980
Costa-Vector Magnitude [188]	n = 26	GT3X+	Direct Observation (CARS)[153,158]	5sec		Counts $5sec^{-1}$	Counts $60sec^{-1}$
2013	Country = England				Sedentary Time	≤ 96.12	≤ 1153
	Age = 2-4years (2.8 years)				Light PA (TotalPA)	> 96.12	> 1153
	Boys n = 13; Girls n = 13				MVPA	≥ 361.94	≥ 4344
Evenson [155]	n = 33	GT1M	Portable metabolic system	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$

2008	Country = USA				Sedentary Time	≤ 25	≤ 100
	Age = 5-8 years (7.3 years)				Light PA (TotalPA)	> 25	> 100
	Boys n = 12; Girls n = 21				MVPA	≥ 57	≥ 2296
Janssen [156] - Recommended	n = 40	GT3X	Room Calorimetry &	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
2013	Country = Australia		Direct Observation		Sedentary Time	≤ 25	≤ 100
	Age = 4-6years (5.3 years)		(CARS)[153,158]		Light PA (TotalPA)	> 25	> 100
	Boys n = 22; Girls n = 18				MVPA	≥ 420	≥ 1689
Pate [197]	n = 29	CSA	Portable metabolic system	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
2006	Country = USA				Sedentary Time	≤ 37	≤ 148
	Age = 3-5years (4.4years)				Light PA (TotalPA)	> 37	> 148
	Boys n = 16; Girls n = 13				MVPA	≥ 420	≥ 1689
			Energy Expenditure Equation:VO2 = 10.0714+0.02366 6counts.15-21				
Puyau [159]	n = 26	CSA	Whole room calorimetry	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
2002	Country = USA				Sedentary Time	≤ 199	≤ 799
	Age = 6-16 (10.7 years)				Light PA (TotalPA)	> 199	> 799
	Boys n = 12; Girls n = 14				MVPA	≥ 799	≥ 3199
			Energy Expenditure Equation:: AEE = 0.0183+0.000010 6counts.60-21				
Reilly [198]	n = 30	WAM-7164	Direct Observation (CPAF) [157]	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
2003	Country = Scotland				Sedentary Time	≤ 274	≤ 1099
	Age = 3-4 years (3.7 years)				Light PA (TotalPA)	> 274	> 1099
	Boys n = 10; Girls n = 20						

Sirard - 3 year old[169] 2005	Calibration n = 5 Validation n = 69 Country = USA	CSA	Direct Observation (CARS)[153,158]	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
					Sedentary Time	≤ 301	≤ 1204
					Light PA (TotalPA)	> 614	> 1204
					MVPA	≥ 1230	≥ 2456
Sirard - 4 year old[169] 2005	Calibration n = 5 Validation n = 125 Country = USA	CSA	Direct Observation (CARS)[153,158]	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
					Sedentary Time	≤ 363	≤ 1452
					Light PA (TotalPA)	> 363	> 1452
					MVPA	≥ 813	≥ 3252
Sirard - 5 year old[169] 2005	Calibration n = 6 Validation n = 75 Country = USA	CSA	Direct Observation (CARS)[153,158]	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
					Sedentary Time	≤ 398	≤ 1592
					Light PA (TotalPA)	> 398	> 1592
					MVPA	≥ 891	≥ 3564
Trost [200] 2012	n = 22 Country = USA Age = 16-35 months (2.1years) Boys n = 8; Girls n = 14	GT1M	Direct Observation (CARS)[153,158]	15sec		Counts $15sec^{-1}$	Counts $60sec^{-1}$
					Sedentary Time	≤ 48	≤ 195
					Light PA (TotalPA)	> 48	> 195
					MVPA	≥ 419	≥ 1673
van Cauwenberghe [199]	n = 18	GT1M	Direct Observation (CARS)[153,158]	15sec		Counts 15sec-1	Counts 60sec-1

2011	Country = Belguim	Sedentary Time	≤ 372	≤ 1488
	Age = 4-6 years (5.8 years)	Light PA (TotalPA)	> 372	> 1488
	Boys n = 10; Girls n = 8	MVPA	≥ 585	≥ 2340

The Costa cut-points are the only known cut-points to be calibrated and validated at the more appropriate 5 second epochs (as described in section 1.2.2.6.4).[188] Using direct observation for both calibration and validation of young children (mean age: calibration n=2.86years; validation n=2.99years), the Costa-Axis 1 cut-points were firstly found to be more accurate than the vector magnitude cut-points, which is unsurprising due to the placement of the monitor being on the hip (as described in section 2.2.5.4). Secondly the Costa-Axis 1 cut-points were found to be more accurate at estimating SB and TPA in comparison to the Pate, Trost and Evenson cut-points, but the Costa-Axis 1 cut-points were found unsuitable to estimate MVPA.

In 2014 Butte and colleagues published more cut-points for young children[152] (Table 1). ActiGraph and Actiheart cut-points were compared with DLW and calorimetry. The results[152] added another set of cut-points which were reported by the authors to be suitable to estimate SB and TPA intensities within young children. There is a real need for the universal acceptance of a singular set of cut-points to measure young children's PA, however that is not the aim of this thesis. Therefore, based upon the reported accuracy for MVPA in both toddlers and preschoolers in comparison to other cut-points (Trost et al[170], and Janssen et al[156]), the Pate MVPA cut-point of ≥420 counts per 15 seconds[197] will be the chosen cut-point for estimating MVPA in Chapters 4 and 5. Based upon the results of Costa et al[188] the calibrated cut points of ≤5 counts per 5 second epochs were found to be the most accurate SB/TPA cut-points leading to being the chosen cut-points for SB in Chapters 4 and 5.

1.2.2.6.6. Duration of monitoring, wear time and non-wear time

Measuring habitual PA in any age group is difficult due to the great variability from one day to another.[201] Variability of a populations PA will not just be between individuals but also largely within individuals.[1,2] For this reason one day of accelerometer measurement is not enough to reliably assess habitual PA. Therefore assessing habitual PA requires measuring PA across multiple days.[135,184] [110,186] A repeated issue when planning to use a PA measure is for researchers to consider their research question (e.g. population or individual PA assessment), logistics (e.g. time scale and budgets of studies), and feasibility (e.g. burden being placed upon participants).[135,182,201] To assess habitual PA via accelerometry researchers must establish their sample has enough minutes on enough days of PA monitoring to reliably do so. While also not sabotaging compliance and accuracy by implementing highly demanding accelerometer protocols.[110,135,187,202] This can be argued to be more important when measuring young childrens habitual PA simply because of their young age, and the added reliance upon parents/care providers to support in wearing the accelerometer correctly (e.g. right hip) and to continue to do so.

How many days required for a reliable measure of habitual PA is a subject of debate, and currently there is no universal answer.[110,175] There are multiple issues researchers need to consider when measuring habitual PA. Firstly what is a feasible duration length participants will be asked to wear accelerometers? Secondly, how many hours in how many days are minimally required to reliably and accurately estimate habitual PA. Thirdly, how do researchers classify non-wear time (i.e. accelerometer has been taken off) from time spent in sedentary behaviour or sleep.

Across children's PA accelerometer literature a seven day duration protocol is consistently advocated. This is because of the variability in children's PA across one week, and a seven day duration would allow the possibility to include weekend days which have been found in older children to be significantly different from weekdays.[135,187,202] However, variability between days of the week has been considered to be less in young children.[110] This is likely because of the absence of attending school every day during the week and having less regimented structure and more free time during the weekends.[110] However, for young children it has been considered a seven consecutive day accelerometer wear protocol is best to maximise the number of days of compliance.[203] It has been suggested by Cliff[110] that three out of seven days of compliance is enough to reliably estimate young children's habitual PA. Cliff[110] also suggested that as young children have longer daily sleep time, and shorter waking time compared to school aged children, and number of hours of wear-time could theoretically be less than school aged children, for which previous studies have frequently applied 8-10 hours of daily wear.[175] However, there is no actual current consensus upon the number of hours and days minimally required, to reliably estimate young children's PA.[175] Cain[175] identified 273 articles within their review on accelerometer methodologies of children. For young children it was concluded wear time ranged from <6-10 hours for a valid day and 2-10 or more days across published studies. Four studies have investigated the amount of wear-time required to reliably estimate habitual PA in young children.[203-206] Conclusions of the studies make it a complex and confusing decision to choose an appropriate wear-time criterion. Penpraze[206] concluded there were no differences in CPM between weekdays and weekends, and to reach high levels of reliability (ICC=0.80) a minimum of 10 hours on seven days is required, but 6 hours on any 5 days would reach acceptable reliability (ICC=0.70). Hislop[204] also found no differences between weekdays and weekend days, but recommend that seven hours on any three days would reach acceptable reliability (ICC=0.70). Addy[203] and Hinkley[205] both found differences between weekdays and weekends. Addy[203] concluded that to reach a reliability of ICC=0.75 a minimum of 6 hours on any 6 days was required for habitual TPA and 5 days for MVPA. Hinkley[205] found the number of days required for reliability decreased while the daily hours increased, but based upon the study's sample suggested 7 hours on 3 weekdays and 1 weekend day would suffice

(ICC=0.70). A consensus across the studies appears to be 6 or 7 hours is an acceptable daily wear time length for young children. However, the number of days and what type of day required are unclear. But the results of the studies are likely to be specific to the individual study samples which may have different types of PA variability from different samples of young children. The current lack of clarity is limiting. This is because including days with few measured hours will increase the risk of underestimating PA levels[201], and excluding participant's valid data could drastically effect sample sizes. This could increase the possibility of biased results and/or the inability to generalise results in larger population studies.[110,187] What is required is simple and clear guidance for researchers to follow in order to justify reliable wear-time periods for their specific study samples of young children.

Another important aspect of measuring PA via accelerometry is the identification and management of missing data. A standard instruction for wearing accelerometers is for them to be worn during all waking hours, and only removed for sleep, or if the monitor is not water proof (when swimming, bathing or showering). An issue with accelerometry data is that it is continuously collected for 24 hours and sleep time or time the monitor has not been worn (non-wear time) can be easily mis-classified as time being sedentary. There is currently no consensus about the choice of methods used to accurately identify non-wear time in all ages of children.[175,185] Three commonly used methods to identify and remove non-wear time are: 1) by comparing accelerometer data with a diary of wear time; 2) removing time for sleep based upon standard sleep times; 3) removing data consisting of continuous zero counts.[1,2]

In relation to young children parents would be asked to complete a wear-time diary by documenting times in which the accelerometer was put on, taken off and for what reasons (e.g. bathing, naps). Relying on this approach alone could be problematic due to relying upon the subjective reporting of parents, who may forget when the monitor was taken off. Removing standard sleep times (e.g. 8 hours of sleep) could be problematic for young children due to the likelihood of nap times. Removing data consisting of continuous zero counts is the most common approach used when cleaning young children's accelerometry data.[175,185] Typically for young children consecutive periods of non-wear time (zero counts) longer than 10 minutes are removed from the data.[175,202] This is based upon the assumption that accelerometers are sensitive to the smallest of movements, thus would register a count value higher than zero if the monitor is worn.[185] The definition of non-wear time is of great importance because if done incorrectly could to lead to confusing sedentary time with missing data, therefore underestimating/overestimating sedentary time; and increasing the likelihood of sampling bias by confounding wear-time leading to incorrectly excluding participants.[185]

1.2.2.6.7. Limitations and other issues

Accelerometers like all measures have limitations. Hip worn accelerometers like pedometers are insensitive to the measurement of non-ambulatory movements such as cycling and upper body movements.[185,191,202] Accelerometers are not able to account for the extra energy cost associated with walking up an incline or stairs, or carrying extra loads.[177, 182, 194] Body posture and the context of PA is not measured by accelerometers.[185,195] Additional monitors such as direct observations, questionnaires or global positioning system (GPS) monitors would need to be included along with accelerometry to measure contextual data. Accelerometers also cannot clearly distinguish between sitting still and standing, therefore lack accuracy in measuring true sedentary behaviour. Finally, arguably the biggest limitation is a lack of standardisation of protocols for: data collection, programming, collection, cleaning and analysis; what outcome measures are reported, and how is best to interpret data outputs.[175,186,187]

Despite these limitations accelerometers still have much greater accuracy compared to questionnaires, diaries and pedometers. Accelerometers are also significantly less burdensome (researcher and participant) and are more feasible within large epidemiological studies compared to other PA objective measures (DLW, calorimetry, direct observation and heart rate monitors).[139]

1.2.2.7. Combination of monitors

Each objective monitor of PA has its limitations and strengths. One method of overcoming limitations is to combine the use of monitors. One example is accelerometry and heart rate monitoring. One of the fundamental limitations of accelerometry is the inability to measure upper limb activities (when placement is on the hip), walking up an incline, and accounting for carrying extra loads (carrying a back pack).[135,136,145,175,185,207] Heart rate monitoring is limited on its own through the reduced accuracy of measuring lower intensity activities, however, is accurate at measuring higher intensity activities.[1,2,145,146] Thus the combination of both methods is logical as the strengths of one monitor compliments the limitations of another.[200,208] However, the combining of monitors increases the burden upon participants, increases the time and cost of projects through increased data cleaning processes, thus limited for large population studies.[136] And with the multiple number of monitors required to be worn a combination of separate units of methods is not practical for young children.[136]

To overcome the problem of separate monitors being worn, devices have been created which combine the use two methods into one device.[4,138,208] Once such device is the called the Actiheart (CamNtech, Cambridge, UK), which is a device that combines accelerometry and heart rate monitoring to improve the accuracy of EE estimation.[138,208] It has been calibrated and validated in adults[208] as well as children.[2,194] In young children a study implementing the Actiheart was undertaken in order to calibrate MVPA.[209] It was found 87-91% of observed MVPA was correctly classified. However, limitations of the Actiheart are the discomfort of attaching electrode pads upon young children, and increasing the risk of allergic reaction, which has been reported to be a concern for parents of 3-6 year olds.[210] However, the Actiheart has successfully been applied within a large cohort study measuring PA of young children.[59,114,209,211]

1.2.3. Subjective Measures

1.2.3.1 Activity diaries

Activity diaries are a measurement tool which have been shown to be valid in measuring PAEE, bouts of PA and the types of activity taken place in adolescents.[212,213] Although diaries are inexpensive they are very burdensome upon participants. In the context of young children, this burden would be placed upon care-providers due to young children not yet developing the cognitive skills to thoroughly recall PA, or understand what PA is. To add, participants recalling their own PA through diaries have found recalling periods shorter than 15 minutes to be counter-intuitive.[212] Physical activity of young children is more spontaneous and intermittent compared to adults themselves[185], therefore it is logical to assume parents will struggle to recall their young child's PA. Supporting this view is also the finding that mothers have been found to overestimate and perceive their young child as being more active than what they actually are[214]; thus leading to the view parental (proxy) reported PA diaries are not suitable to measure young children's PA.

1.2.3.2. Questionnaires

Questionnaires have widely been implemented as a method within the study of PA; a systematic review in 2013 conducted by Helmerhorst[215] summarised the reliability and validity of 130 published questionnaires across the whole spectrum of age groups (early years, children, adolescent, adults and older people). Because young children, particularly early years do not have the capacity to comprehensively reflect and/or recall past behaviours[216] proxy reported questionnaires like activity diaries relying upon a parent or care provider (guardian, teacher, carer) are commonly used.[216] The difference between diaries and questionnaires, are that questionnaires have questions and prompts about dimensions and domains of PA, which aid participants in the recalling of their own behaviour or that of their child's. Diaries are less specific and may ask how many minutes overall PA or intensity took place each day leading to possible greater bias.[135]

For young children there have been multiple uses for specific questions about PA within different domains (e.g. how many minutes was the child active outside, how many times does your child play sport at preschool).[135] However, the comparison of these questions to a more accurate objective measure within validity studies has been sparse. There are however, two known proxy questionnaires which estimate young children's habitual PA, and have been reported have acceptable reliability and validity.[217,218] The Preschool-age Physical Activity Questionnaire (Pre-PAQ)[219] was developed in Australia. The study sample consisted of 103 children with a mean age of 3.3 years. The test re-test reliability (assessed using intra-class correlations ICC(2,1)) across seven days ranged from 0.44 for stationary activities (sedentary), 0.54 for moderate and fast physical activity (MVPA) and 0.61 for slow to fast physical activity (total physical activity). Corder[218] conducted a study which determined the reliability and validity of four physical activity questionnaires across different age groups of children. One questionnaire titled the Children's Physical Activity Questionnaire (CPAQ) was administered to a group of young children (n = 27, 4.9 years SD = 0.7) from Cambridgeshire, United Kingdom.[218] Test retest reliability of the CPAQ (7 days between two tests) was found to be lower than that of the Pre-PAQ, with an ICC of 0.25 for total physical activity and an ICC of 0.39 for MVPA.

In relation to validity, habitual PA measured by the C-PAQ was compared to habitual energy expenditure measured using doubly-labelled water and accelerometry.[218] There were no significant correlations between reported time in C-PAQ MVPA and accelerometer determined MVPA, with two cut-points (3000 CPM[220] and 1952 CPM[178]) utilised. The mean bias was 235.9±362.0 mins per week (3000 CPM) and -76.5 mins per week (1952 CPM). The CPAQ's TPA compared to AEE measured by DLW found mean bias was nearer to zero (-14.4 minutes per week) and was found to have a non-significant correlation (= -0.36). For the Pre-PAQ, Dwyer[219] recruited 67 children aged 3.8 years of age who also wore an uniaxial accelerometer (model MTI 7164). Dwyer[219] applied two different cut-points for sedentary behaviour and TPA[169,198] and one cut point for the measure of MVPA[169]. Applying the Reilly[198] (274 counts per 15 seconds) cut point found that there was a significant correlation between the Pre-PAQ and the accelerometer for sedentary behaviour ($r = 0.28$ $p \leq 0.05$), however the mean daily minutes of difference (bias) was large, with the Pre-PAQ under reporting daily minutes by -208.6 min per day (limits of agreement (LOA) = -349.8 to -67.5). Sedentary behaviour using the Sirard[169] cut-points found no significant correlation ($r = 0.19$) with the accelerometer, with large mean differences (-235.4 min per day (LOA - 383.1 to -87.7)). The Pre-PAQ was also found to be weakly correlated ($r = 0.17$, $p \leq 0.05$) and overestimated MVPA (50.1 min per day (LOA -42.9 to 143.1) using cut-points by Sirard[169] For TPA, it was found the Pre-PAQ over estimated TPA (Reilly: 20.9 min, LOA =-121.9 – 163.7; Sirard: 45.2 min, LOA -103.6 – 194.1) and again had non-significant weak correlations (Reilly: $r = 0.16$; Sirard: $r = 0.05$). The final conclusions were both the Pre-PAQ and C-PAQ were suitable to measure PA (TPA and MVPA) of young children at the population level, but only the C-PAQ is suitable to rank individuals MVPA not TPA. What is clear is the accuracy of questionnaires are inferior to objective measures, but researchers should consider the strengths, weaknesses, feasibility and capabilities of each PA measure according to research questions before a measure is decided upon.

In conclusion, there are no current gold standard methods of measuring of PA. Each choice of methods has strengths and limitations, which have been discussed where possible in relation to young children in the second part of this chapter. Considering issues of PA methods and that young children's habitual PA is the main outcome for the original studies of this thesis, the two primary methods of interest for this thesis are accelerometry and proxy reported questionnaires.

CHAPTER 2 – Outline, aim and objectives

2.1. Rationale of thesis

In Chapter 1 a literature review of young children's PA covered the first three stages of the behavioural epidemiological framework (Figure 2.1). Physical activity is a complex behaviour and although the research area within young children's PA is limited in areas, previous research indicates and supports the need to promote and increase PA as a public health priority within western developed countries, such as the UK; which has been through the physical activity transition, and is now suffering the consequences of high levels of inactivity.[20,23,27,32,42,107,134,221] Currently it is reported many young children do not engage in enough PA, particularly MVPA.[112,114,130] Previous research suggests engaging in large volumes of PA on a daily basis will not only provide health benefits in the short term[27] (during the early years) but also in the medium term;[118,222] due to the tracking of PA from the early years to the primary school years.[13,14] Many young children will be entering their fifth birthday and getting ready for school not reaching a minimum of 60 minutes of MVPA on a regular daily basis, meaning the greater likelihood of being inactive throughout the rest of their childhood years, and thus have a greater risk of the health consequences associated with inactivity.[118,120,222-224] In order to inform future interventions and a greater likelihood of intervention efficacy, an understanding of the correlates and determinants of young children's PA is vital.[83,84,132-134,225] Previous research has been limited through measurement inconsistencies[1,127,182,185,196] and a sparse number of studies have been conducted within multi-cultural and deprived communities.[17,89,226,227] Following an ecological[132,228] and bio-cultural perspective[229] it is hypothesised that a one size fits all approach for future PA intervention design is illogical; as what influences habitual PA (domains, familial influences and dynamics) is probably different for children from different cultural and ethnic backgrounds.[229] Understanding the correlates of PA in young children of SA ethnicity is particularly of public health concern due to the increase risk South Asian's have of non-communicable diseases.[17,227,230-232]

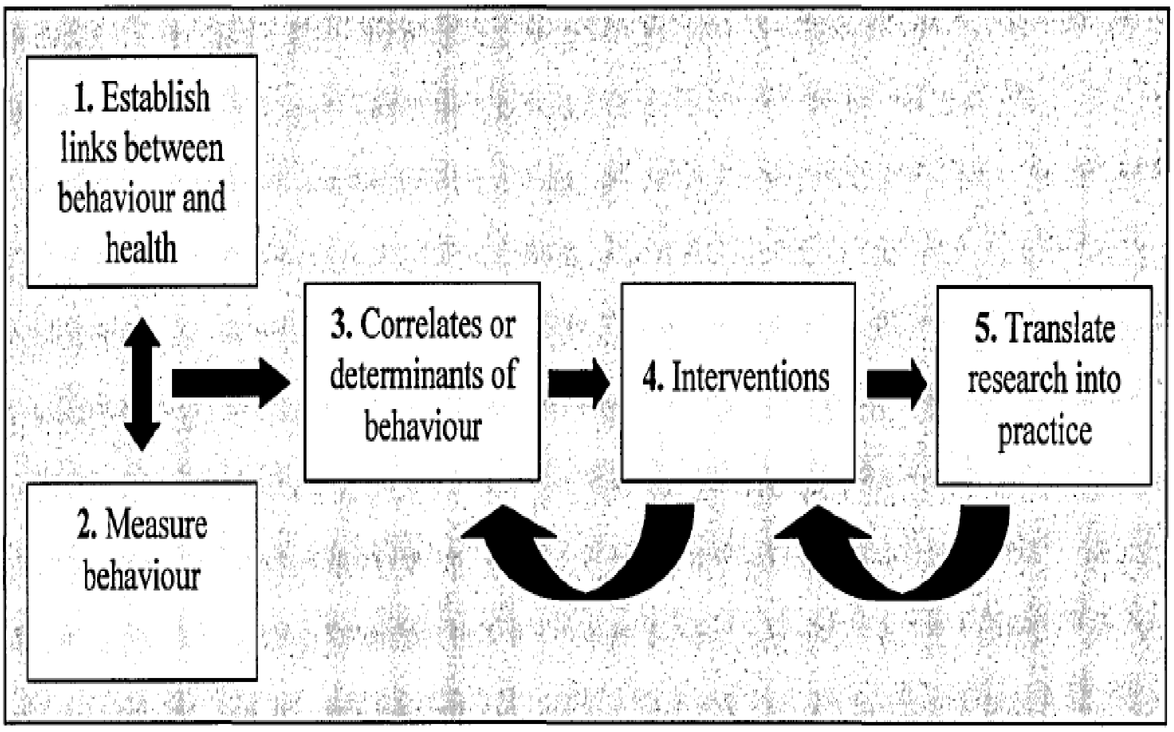

Figure 2.1: Behavioural epidemiological framework

This thesis will focus upon two areas of the behavioural epidemiological framework[225] examining aspects of the measurement of PA in early years children and determining the correlates of PA of young children from a multi-cultural, bi-lingual and low socio-economic status community.

2.2. Aims

The aims of this thesis were:

I. To systematically review previous published research in order to establish currently known correlates and determinants of PA in the early years (0-6 year olds) and identify gaps within the literature to explore.

II. To calculate an accelerometer wear-time criteria to reliably measure young children's habitual physical activity.

III. To investigate the validity and test re-test reliability of the Early Years Physical Activity Questionnaire (EY-PAQ), a parental proxy reported questionnaire.

IV. To investigate the levels and correlates of moderate-to-vigorous physical activity in 2 year old children from a multi-ethnic, multi-linguistic population using the EY-PAQ data from the Born in Bradford Cohort.

2.3. Structure of the thesis

An introduction and critical review of the physical activity literature occurred in Chapter 1. This chapter, Chapter 2 sets out the aims and flow and interconnectivity of the other chapters of the thesis. Chapters 3 to 6 each flow on from one another and contribute to the structure of the thesis (Figure 2.2), but each Chapter can also be read as standalone research studies:

Chapter Three – This chapter is a comprehensive systematic review which synthesized published peer-reviewed research investigating potential correlates and determinants of TPA, MVPA, and LPA of children during the early years (ages 0-6). The review also examined the potential differences in identified associations by measurement method (objective and subjective measures). After the review process a total of 130 published research articles were included in the evidence synthesis. Key findings of the review were: all studies took place in high income countries, a small number were of high quality (n=9), of the few identified correlates and determinants most were demographical/biological and social/cultural variables/factors; and findings were consistent between objective and subjective measures used. A number of key gaps in the research were identified, which informed the direction of the rest of the studies in the thesis. Gaps in the literature were few studies investigated the correlates of toddlers MVPA, or ethnic differences in MVPA between White and South Asian populations of young children.

Chapter Four –The availability of comprehensive birth cohort data, including a proxy-report MVPA and ST questionnaire of two year old children living in a predominate bi-ethnic community (the city of Bradford, UK), offered an opportunity to address some the research gaps identified in Chapter 3 (i.e. toddlers, MVPA and ethnicity). In order to pursue this opportunity an investigation of the validity and test re-test reliability of proxy-report MVPA questionnaire needed to take place, using accelerometry as the criterion measure. This chapter preluded the validity and reliability investigation (Chapter Five) in order to estimate a population specific accelerometry wear-time, to reliably estimate habitual PA levels of young children living in the city of Bradford. This study, using a simple and clear stepped approach objectively informed an accelerometer wear-time protocol which maximised the sample size of the validity study in Chapter Five, while maintaining high reliability (ICC = 0.7).

Chapter Five – Reported in this chapter is a study which used accelerometry as a criterion measure (and the wear-time criteria calculated in Chapter Four) to examine the validity and test re-test reliability of the previously mentioned MVPA and ST proxy-report questionnaire, called the 'Early Years Physical Activity Questionnaire' (EY-PAQ). The study consisted of a sample of 2-4 year old children who wore a hip-accelerometer for 7 days, and one parent completed the EY-PAQ on two occasions (in English or Urdu-depending on language preference), first when the accelerometer was fitted on the children and second seven days later when the accelerometer was collected. In comparison to other proxy-report questionnaires it was found the EY-PAQ had acceptable validity and test re-test reliability in estimating habitual MVPA of young children living the city of Bradford, whether the questionnaire was completed in English or in Urdu.

Chapter Six – In this chapter a large cross-sectional study, using data from the Born in Bradford birth cohort, was undertaken to investigate the levels and correlates of 2 year old children's MVPA (measured using the EY-PAQ). The large sample size allowed the data to be stratified by ethnicity, and to examine a large number of potential correlates covering different levels of the ecological model. Results of this study are discussed in relation to previous research and how these findings can contribute and inform future research, especially future interventions.

Chapter seven – This final chapter discusses the findings and implications of the previous four studies, and outlines directions for future research.

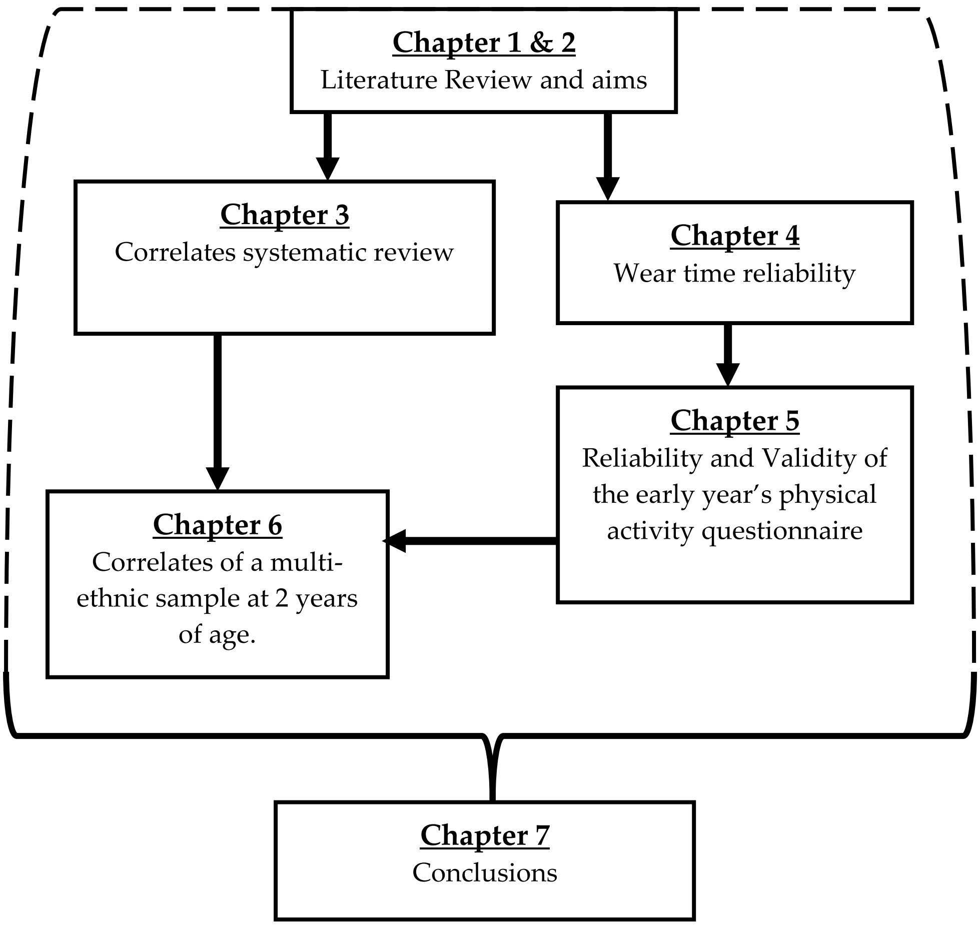

Figure 2.2: A flow-diagram outlining the interconnectivity of chapters.

2.3. My role

For the duration of the PhD, I Daniel Bingham, was based at the Bradford Institute for Health Research, and was part of the research team working within the Born in Bradford (BiB) Birth Cohort study. BiB is a unique cohort study, which is not only a birth cohort, but is also a cohort which utilises data collected, along with a well-established brand in the city of Bradford to apply for funding to pursue separate studies within Bradford, which may not include participants from the birth cohort. One such example is the National Institute for Health Research (NIHR) funded study: *Preschoolers in the Playground (PiP) – a feasibility clustered randomised control trial*. The data used for the original studies in this thesis derived from the PiP (chapters 4 and 5) BiB cohort data (chapter 6).

My role as a PhD student evolved during the PhD. I first began working with BIB community assistants on the first wave of the PiP project. I helped with the finalising of the protocol, recruitment (consent) of schools and parents, data collection and co-authored the full report. Data collection consisted of visits to parents and young children's homes. During a visit, I measured children's height, weight, upper arm circumference, abdominal circumference, explained the use of an accelerometer to parents, fitted an accelerometer on the child and conducted the PiP questionnaire. My role evolved from being a research assistant in the first wave of data collection (Autumn 2012) to that of research fellow in the final data collections of PiP (Waves 3 and 4, Spring-Winter 2013), which entailed me recruiting schools and co-ordinating and managing other research assistants. I was also a member of the trials management steering group and had the responsibility of the trials accelerometer data processing and cleaning.

For the study presented in Chapter 4, I pooled previously collected accelerometer data (sub sample of the cohort) with PiP baseline accelerometer data. I ensured that the PiP protocol was updated in accordance with the same protocol as the previously collected BiB accelerometer data. This ensured pooling of data could take place. I cleaned, processed and analysed data in accordance with the studies objectives and aims.

For the study presented in Chapter 5, I amended the PiP NHS ethics and included a physical activity questionnaire (Early Years Physical Activity Questionnaire) to the trials questionnaire during Waves 2 and 3 of the study (Spring-Summer 2013). I then trained research assistants in the collection of the questionnaire, and I also collected many questionnaires myself. I then inputted questionnaire data, processed, cleaned and analysed all other data in accordance with the studies' objectives and aims.

For the study presented in Chapter 6, I utilised the BiB cohort data. I applied and presented the study proposal and analysis to the BiB executive committee. I was successful with my application and the executive committee granted me permission to use cohort data for the proposed study. I then cleaned and analysed data in accordance with the studies objectives and aims.

CHAPTER 3 – The correlates and determinants of physical activity during the early years: a systematic review

The study in this chapter has been:

Presented at the International Society of Behavioural Nutrition and Physical Activity (ISBNPA) annual meeting 2015

Published in the American Journal of Preventive Medicine:

Bingham DD, Costa S, Hinkley T, Shire KA, Clemes SA, Barber SE. Physical activity during the early years: a systematic review of correlates and determinants. *American Journal of Preventive Medicine*, 2016;51(3):384–402.

3.1 Introduction

Physical activity (PA) is a key influence upon health across the life course.[233-236] The "early years" is an umbrella term for an age range that encompasses infants (0-1 years), toddlers (1-3 years), and preschoolers (3-5 years).[27] During this period, PA is reported to be associated with multiple health outcomes.[27] Evidence suggests PA levels track from early to later childhood,[118] and into adulthood,[120] so establishing optimal levels of this health-related behaviour early in life is crucial.[237,238] Whether children during the early years are sufficiently active is unclear. Some studies have reported that children largely fail to meet current PA guidelines,[130] and spend most of their time inactive,[111,239] while others have reported sufficient activity levels in this age group.[240,241] Because of the link between PA and health it is important to understand correlates and determinants of PA to enable the development and implementation of effective interventions;[242] particularly as previous interventions have had limited efficacy.[243]

For the purposes of this review, the term 'correlate' is used when an independent variable is found to be associated with PA in cross-sectional studies and thus causality cannot be determined. The term 'determinant' is used when an association is found between an independent variable and PA in longitudinal studies[60] where temporal associations over time may be observed, although there is still a risk of bidirectional or reverse causality pathways.[244] It is essential for researchers to have an understanding of the correlates and determinants of PA in order to identify possible at risk demographic groups and/or mediators to be targeted in future intervention studies.[60]

Physical activity is a multi-dimensional behavior with correlates and determinants present across different levels of the ecological model (e.g. individual, social and physical environments).[83,130-134] Identifying variables associated with PA at different levels of the ecological model allows researchers to intervene at various levels to attempt to increase young children's PA.[83,130-134]

Previously a large amount of research has already been conducted upon the correlates and determinants of young children's physical activity research. However, PA research is still within its infancy and is constantly evolving, particularly in regard to the greater efficacy of methods being able to measure physical activity, especially objective tools, and the greater accuracy of evolving refinement of data derived from objective tools. Observational studies which lead to identification of correlates and determinants, cannot assert causality but rather associations between exposure variables with physical activity. Only intervention studies which are correctly powered can detect a causal link between an exposure variable and physical activity, but with physical activity being a human behaviour that occurs daily (a human being is either asleep, sedentary or physically active), many variables across the ecological model may have a causal link with physical activity. The benefit of correlates and determinants research is the relative ease of conducting, and most importantly generating hypotheses which inform which exposure variables could be tested within experimental study designs. Therefore, conducting and updating correlate systematic reviews every few years is worthwhile and informs researchers and policy makers planning interventions which exposure variables to consider including and testing. Two previous systematic reviews,[83,84] which adopted the use of the ecological model, reviewed the correlates of PA in children during the early years. Neither review investigated the correlates or determinants of the different intensities of PA (light-intensity PA [LPA], moderate- to vigorous-intensity PA [MVPA]). Physical activity guidelines for children during the early years place an emphasis upon the promotion of total PA (TPA). However, identifying correlates and determinants of MVPA is also of public health importance as time spent in MVPA has been associated with benefits to bone/skeletal development,[245] adiposity[59] and metabolic status.[68]

Young children's PA is sporadic and intermittent.[4,246] Because of these patterns subjective and objective measures of PA capture different behaviours/constructs. Subjective measures typically require parents to recall children's PA (e.g. active play and walking) which are susceptible to recall errors and bias, such as social desirability bias.[2,127,215] Objective measures directly capture parameters of PA such as movement, acceleration, and heart rate.[4] Objective monitoring avoids the biases associated with subjective measures and is more sensitive to sporadic patterns of PA.[2,127,215] Thus, the type of measure used by studies should be considered when investigating correlates and determinants.

3.2. Aims

The aims of this systematic review were to synthesize studies investigating potential correlates and determinants of TPA, MVPA, and LPA in children during the early years and investigate potential differences in associations by measurement method.

3.3. Methods

3.3.1. Search Strategy

The search and review process followed guidance from the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[247] A systematic literature search was conducted within nine electronic databases: Web of Science, SCOPUS, SPORTDiscus, PubMed, Cochrane, Pro-Quest, PyschInfo, Embase and CINHAL. Each database was searched from the year of inception (i.e. the earliest was Web of Science, 1900) until September 2014. Data extraction and interpretation took place between November 2014 and April 2015. Key words relating to behaviour(s) (i.e. physical activity, exercise, play, physical fitness, physical inactivity, sedentary, sport, health behavior and motor movement), in conjunction with population (i.e. child, children, kindergarten, preschool, early years, infant, toddler) were used for the search. Authors' bibliographies and papers which had cited the De Craemer[83] and Hinkley[84] reviews were also searched.

3.3.2. Inclusion Criteria

To be included, studies had to: 1) have an observational design; 2) be written in English; 3) be published in a peer-reviewed journal; 4) explore potential associations between PA as a quantitatively-measured outcome variable and independent variable/s; and 5) have a sample (or sub-group) aged 0-6 years not in statutory/school education. The age range is increased to 6 years of age due to many countries having the age of entering statutory/school education beginning at 6 years of age, so preschoolers in this review were aged 3-6 years of age. An example of search strategy used is found in Appendix 3.1, and example of the inclusion/exclusion form is found in Appendix 3.2.

3.3.3. Reporting of Results

If more than one instrument measured the same PA outcome (e.g. parent-reported and accelerometer-measured MVPA) in a study, only data from the most valid instrument were included. If validity data were not reported, the result from the most objective method was chosen. If two measures were used for separate outcomes, separate associations were included. Studies that used different PA contexts (e.g. recess, physical education) are highlighted in appendices. Similar to a previous review,[84] this review found no difference in the percentage of null associations per study using multivariate analysis compared with results from bivariate analyses (t-test, p=0.20); therefore, results taken from bivariate and multivariate analyses were included together and marked accordingly. If potential correlates and determinants of moderate-intensity PA (MPA) and vigorous-intensity PA (VPA) were reported separately but in the same direction, the results were combined for one overall association with MVPA. This same process was used to report associations of potential correlates/determinants with TPA: if associations of a variable with LPA, MPA, and VPA were reported separately, but in the same direction, the results were combined. If an association was found for one intensity of PA (e.g. VPA) but not the other (e.g. MPA), associations were reported separately. Result tables report the number of studies in each direction of association (positive, negative or null). Tables also report the overall summary of associations for each variable, along with the separate summaries of studies using an objective or subjective outcome measure. Tables within the appendices provide a detailed overview of the variables included in individual studies.

3.3.4. Search Process

One reviewer (Daniel David Bingham: 'DDB') undertook the initial search of article titles. Two reviewers (DDB and Katy Anna Shire 'KAS') then independently screened the article abstracts. Any discrepancies between the reviewers were discussed until consensus was achieved. If consensus could not be achieved, further discussion was undertaken with a third reviewer (Sally Elizabeth Barber: SEB) to achieve consensus. This process was repeated when reviewing the full articles. Data extraction was undertaken using a standardized form (appendix 3.2).

3.3.5. Selection of variables

Categories of potential correlates/determinants were: 1) demographic and biological, 2) psychological, cognitive and emotional, 3) behavioral, 4) social and cultural, and 5) physical-environment. The overall strength of association between PA and each potential correlate/determinant was assessed by examining the percentage of studies reporting an association in a given direction.[132] For correlates, if the association with PA was tested <4 times, no classification was graded. If ≥4 studies had tested an association, and 0-33% reported significant associations in a positive/negative direction, the result was categorized as no association (0). If 34-59% reported significant associations in a consistent direction, the result was categorized as inconsistent (?). If 60-100% reported a significant association in a consistent direction, the result was coded as (+) for positive or (-) for negative associations.

For determinants, a classification was graded even if the potential association was assessed ≤4 times. This decision was made due to the greater importance of determinants compared to correlates. The following coding procedure was used to incorporate the quality assessment outlined by Costigan[248] and Lubans[249]: if 60-100% of high quality studies reported consistent findings (positive, negative or null association), the result was coded as strong evidence in that direction (++, -- ,00). A potential correlate/determinant was considered a correlate/determinant when a positive or negative association (+,++,-,--) was found.

3.3.6. Study methodological quality

Two reviewers (DDB and KAS) independently assessed study quality using criteria adapted from the CONSORT[250] and STROBE[251] statements, used in previous systematic reviews.[33,34] A score for each study was completed on a 6-point scale by assigning a value of zero (absent and/or insufficiently described) or one (present and/or clearly described) to the following questions: Q1) did the study describe participant eligibility criteria? Q2) were participants randomly selected? Q3) did the study report the sources and details of PA assessment and did the instruments have acceptable reliability for the specific age group (e.g. an intra-class correlation coefficient (ICC) of 0.70 or Pearson correlation of 0.80 was considered acceptable)?

Q4) did the study report the sources and details of assessment of correlates/determinants and did all instruments have acceptable reliability? Q5) did the study report a power calculation and was the study adequately powered to detect hypothesized associations? Q6) did the study report the numbers of participants who completed each of the different measures? Studies scoring 0-2 were regarded as low quality/high risk of bias; studies scoring 3–4 were considered moderate quality/risk of bias; and studies scoring 5-6 were considered high quality/low risk of bias.

3.4. Results

3.4.1. Review Process

Figure 3.1 outlines the flow of articles through the review. A total of 22,045 articles were identified and screened; 19,385 were excluded based on the title (mostly due to their sample's age falling outside the inclusion criteria), and a further 1,733 were identified as duplicates and excluded. Of the remaining 927 abstracts, 490 were excluded. 437 full articles were screened and 332 excluded, leaving 105 articles. A further 25 articles were included from hand searching and authors' private libraries, leaving 130 articles for data extraction. Details of the included studies are outlined in Appendix 3.3.

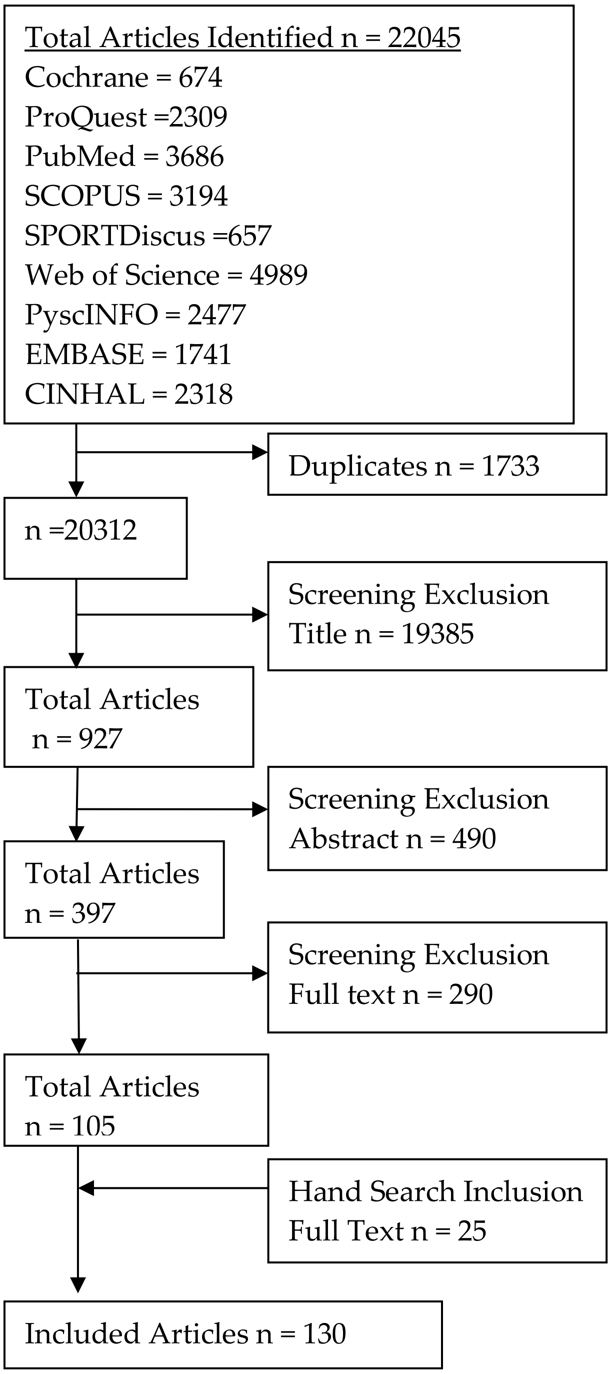

Figure 3.1: Flow diagram of the systematic review literature search.

3.4.2. Study Design

The majority of studies were cross-sectional (n=115, 88%); 11 (9%) were prospective;[154,155,222,252-259] three (2%) were intervention studies[210,260,261] (baseline data only) and one was an intervention study reporting no intervention effect; therefore, data from the control and intervention groups were combined and a longitudinal/prospective analysis reported.[153] Of the 12 prospective studies, three[155,222,259] had a follow-up period which went beyond the early years, meaning only baseline data were included. Therefore, nine studies[153,154,252-258] investigating potential determinants were included. In total, 114 studies investigated potential correlates of TPA, 73 investigated correlates of MVPA, and 25 investigated correlates of LPA. For those studies which investigated potential determinants, all nine investigated associations of those potential determinants with TPA, two with MVPA, and one with LPA.

3.4.3 Study Quality and Methodological Risk of Bias

The ICC between the reviewers' quality scores was 0.97. Table 3.1 outlines the quality score (low, moderate, high) for each study. A total of 122 (93%) adequately described eligibility criteria (Q1); 103 (79%) adequately described their process of randomly selecting participants (Q2); 25 (19%) adequately described their assessment of PA (Q3); and 38 (29%) adequately described their assessment of correlates/determinants (Q4). No studies reported the use of a power calculation (Q5), whereas 90 (69%) reported the number of participants with complete measures (Q6). Nine (6%) studies were identified as high quality,[130,156,157,255,262-267] two of which were determinant studies;[257,263] 78 (60%) were classified as moderate quality,[4,58,59,153,154,158,159,167,189,199,200,208,210,217,222,239,252,254,256,258,259,261,268-313,63,314-319] of which seven were determinant studies[254] [284] [256] [252] [259] [285] [258] and 43 (33%) were classified as low quality,[70,103,114,155,183,184,194,206,209,240,241,253,260,320-349] with only one determinant study[253] (Table 3.1).

Table 3.1: Included study quality check list and level of quality and study design.

Study [No]	Question 1 *Eligibility*	Question 2 *Random Selection*	Question 3 *PA Reliability*	Question 4 *Correlate Reliability*	Question 5 *Power*	Question 6 *No. Participants*	Total (0-6)	Level of Quality*	Study Design**
Adams[320]	1	1	0	0	0	0	2	Low	Cross
Anderson[321]	1	1	0	0	0	0	2	Low	Cross
Baranowski[254]	1	1	1	1	0	0	4	Moderate	**Pro**
Barkley[268]	1	1	0	0	0	1	3	Moderate	Cross
Becker[350]	1	0	0	1	0	0	2	Low	Cross
Beets[262]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
Bellows[260]	1	1	0	0	0	0	2	Low	Inter-B
Benham-Deal[269]	1	1	0	0	0	1	3	Moderate	Cross
Blaes[270]	1	1	0	0	0	1	3	Moderate	Cross
Boldemann[271]	1	1	0	1	0	0	3	Moderate	Cross
Bower[272]	1	1	0	1	0	1	4	Moderate	Cross
Brasholt[351]	0	0	0	0	0	1	1	Low	Cross
Brown[273]	1	1	1	0	0	0	3	Moderate	Cross
Brown[352]	1	1	0	0	0	0	2	Low	**Pro**
Burdette[322]	1	1	0	0	0	0	2	Low	Cross
Burdette[274]	1	1	0	1	0	0	3	Moderate	Cross
Burgi[263]	**1**	**1**	**1**	**1**	**0**	**1**	5	**High**	**Pro**
Burgi[255]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
Buss[70]	1	0	0	0	0	0	1	Low	Cross
Cardon[275]	1	1	0	0	0	1	3	Moderate	Cross
Cardon[239]	1	1	0	0	0	1	3	Moderate	Cross

Study [No]	Question 1 *Eligibility*	Question 2 *Random Selection*	Question 3 *PA Reliability*	Question 4 *Correlate Reliability*	Question 5 *Power*	Question 6 *No. Participants*	Total (0-6)	Level of Quality*	Study Design**
Caroli[323]	1	1	0	0	0	0	2	Low	Cross
Cespedes[353]	1	1	0	0	0	1	3	Moderate	Inter-B
Chuang[354]	1	1	0	0	0	0	2	Low	Cross
Cliff[189]	1	1	0	1	0	1	4	Moderate	Cross
Collings[59]	1	0	0	1	0	1	3	Moderate	Cross
Cox[276]	1	1	0	1	0	1	4	Moderate	Cross
Davies[264]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
Dowda[278]	1	1	1	1	0	0	4	Moderate	Cross
Dowda[277]	1	1	0	1	0	0	3	Moderate	Cross
Driessen[355]	1	1	0	0	0	1	3	Moderate	Cross
Dwyer[217]	1	1	1	0	0	1	4	Moderate	Cross
Edwards[356]	0	0	0	0	0	1	1	Low	Cross
Eriksson[324]	1	0	0	0	0	1	2	Low	Cross
Espana-Romero[325]	1	0	0	0	0	1	2	Low	Cross
Fernald[253]	1	1	0	0	0	0	2	Low	**Pro**
Finn[265]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
Firrincieli[326]	1	1	0	0	0	0	2	Low	Cross
Fisher[279]	1	1	0	1	0	0	3	Moderate	Cross
Gagne[266]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
Grigsby-Toussaint[327]	1	1	0	0	0	0	2	Low	Cross
Grontved[328]	1	1	0	0	0	0	2	Low	Cross
Grzywacz[357]	0	0	0	0	0	0	0	Low	Cross
Gubbels[281]	1	1	0	0	0	1	3	Moderate	Cross
Gubbels[280]	1	1	1	0	0	1	4	Moderate	Cross

Study [No]	Question 1 *Eligibility*	Question 2 *Random Selection*	Question 3 *PA Reliability*	Question 4 *Correlate Reliability*	Question 5 *Power*	Question 6 *No. Participants*	Total (0-6)	Level of Quality*	Study Design**
Gunter[330]	1	1	0	0	0	0	2	Low	Cross
Heelan[282]	1	1	0	0	0	1	3	Moderate	Cross
Hesketh[358]	1	0	0	0	0	1	2	Low	Cross
Hesketh[359]	1	0	0	0	0	1	2	Low	Cross
Hinkley[283]	1	1	1	1	0	0	4	Moderate	Cross
Hinkley[360]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
Hnatiuk[284]	1	1	1	0	0	1	4	Moderate	**Pro**
Hnatiuk[361]	1	0	0	1	0	1	3	Moderate	Cross
Iannotti[256]	1	1	1	0	0	1	4	Moderate	**Pro**
Iivonen[362]	1	1	0	1	0	1	4	Moderate	Cross
Jackson[252]	1	1	0	0	0	1	3	Moderate	**Pro**
Jago[259]	1	1	0	0	0	1	3	Moderate	**Pro**
Janz[285]	1	1	1	0	0	1	4	Moderate	**Pro**
Janz[222]	1	1	0	0	0	1	3	Moderate	Cross
Jimenez-Pavon[363]	1	1	1	0	0	1	4	Moderate	Cross
Kambas[286]	1	1	0	1	0	1	4	Moderate	Cross
Kelly[287]	1	1	0	0	0	1	3	Moderate	Cross
Kimbro[288]	1	1	0	0	0	1	3	Moderate	Cross
Klesges[289]	1	1	1	0	0	1	4	Moderate	Cross
Kuepper-Nybelen[290]	1	1	0	0	0	1	3	Moderate	Cross
LaRowe[331]	1	1	0	0	0	0	2	Low	Cross
Laukkanen[291]	1	1	0	1	0	1	4	Moderate	Cross
Lawrence[292]	1	1	0	0	0	1	3	Moderate	Cross
Loprinzi[295]	1	1	0	0	0	1	3	Moderate	Cross

Study [No]	Question 1 *Eligibility*	Question 2 *Random Selection*	Question 3 *PA Reliability*	Question 4 *Correlate Reliability*	Question 5 *Power*	Question 6 *No. Participants*	Total (0-6)	Level of Quality*	Study Design**
Loprinzi[293]	1	1	0	1	0	0	3	Moderate	Cross
Loprinzi[294]	1	1	0	1	0	0	3	Moderate	Cross
Louie[332]	1	0	0	0	0	1	2	Low	Cross
Marino[296]	1	1	0	0	0	1	4	Moderate	**Pro**
McKee[297]	1	0	1	0	0	1	3	Moderate	Cross
McKee[333]	1	0	0	0	0	1	2	Low	Cross
Metallinos-Katsaras[334]	1	1	0	0	0	0	2	Low	Cross
Mickle[335]	1	1	0	0	0	0	2	Low	Cross
Montgomery[298]	1	1	0	0	0	1	3	Moderate	Cross
Moore[58]	1	1	0	0	0	1	3	Moderate	Cross
Niederer[364]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	Cross
O'Connor[365]	1	1	0	1	0	1	4	Moderate	Cross
O'Dwyer[366]	1	1	0	0	0	1	3	Moderate	Inter-B
O'Dwyer[336]	1	1	0	0	0	0	2	Low	Cross
O'Dwyer[261]	1	1	0	0	0	1	3	Moderate	**Inter-Pro**
Olesen[367]	1	1	0	1	0	1	4	Moderate	Cross
Oliver[299]	1	1	0	0	0	1	3	Moderate	Cross
Ostbye[368]	1	0	0	0	0	1	2	Low	Cross
Pate[301]	1	1	0	0	0	1	3	Moderate	Cross
Pate[300]	1	1	0	1	0	1	4	Moderate	Cross
Pate RR[302]	1	1	0	0	0	1	3	Moderate	Cross
Penpraze[206]	1	0	0	0	0	1	2	Low	Cross
Pfeiffer[303]	1	1	0	1	0	1	4	Moderate	Cross
Poest[304]	1	1	0	0	0	1	3	Moderate	Cross

Study [No]	Question 1 *Eligibility*	Question 2 *Random Selection*	Question 3 *PA Reliability*	Question 4 *Correlate Reliability*	Question 5 *Power*	Question 6 *No. Participants*	Total (0-6)	Level of Quality*	Study Design**
Raustorp[338]	1	0	0	0	0	1	2	Low	Cross
Rice[369]	1	0	1	1	0	1	4	Moderate	Cross
Saakslahti[267]	1	1	0	0	0	1	3	Moderate	Cross
Sallis[339]	1	1	0	0	0	0	2	Low	Cross
Sallis[370]	1	1	0	0	0	1	3	Moderate	Cross
Schary[305]	1	1	0	1	0	0	3	Moderate	Cross
Shen[306]	1	0	1	0	0	1	3	Moderate	Cross
Sigmund[307]	1	1	0	0	0	1	3	Moderate	Cross
Smith[308]	1	1	0	0	0	1	3	Moderate	Cross
Spurrier[340]	1	1	0	0	0	0	2	Low	Cross
Sugiyama[309])	1	1	0	0	0	1	3	Moderate	Cross
Sundberg[341]	1	0	0	0	0	1	2	Low	Cross
Tanaka[311]	1	1	0	0	0	1	3	Moderate	Cross
Tanaka[310]	1	1	0	0	0	1	3	Moderate	Cross
Tanaka[371]	0	0	0	1	0	1	2	Low	Cross
Tandon[317]	1	1	0	0	0	1	3	Moderate	Cross
Tandon[318]	1	1	0	0	0	1	3	Moderate	Cross
Taylor[257]	**1**	**1**	**1**	**1**	**0**	**1**	**5**	**High**	**Pro**
Taylor[258]	0	0	1	1	0	1	3	Moderate	**Pro**
Temple[342]	1	1	0	0	0	0	2	Low	Cross
Trost[312]	1	1	0	0	0	1	3	Moderate	Cross
Vale[241]	1	1	0	0	0	0	2	Low	Cross
Vale[343]	1	1	0	0	0	0	2	Low	Cross
Vale[372]	1	1	0	0	0	1	3	Moderate	Cross

Study [No]	Question 1 *Eligibility*	Question 2 *Random Selection*	Question 3 *PA Reliability*	Question 4 *Correlate Reliability*	Question 5 *Power*	Question 6 *No. Participants*	Total (0-6)	Level of Quality*	Study Design**
Vale[373]	1	1	0	0	0	1	3	Moderate	Cross
van Rossem[313]	1	1	0	0	0	1	3	Moderate	Cross
van Sluijs[374]	0	0	0	0	0	1	1	Low	Cross
Vanderloo[375]	0	0	0	0	0	0	0	Low	Cross
Vanderloo[319]	1	1	0	0	0	1	3	Moderate	Cross
Vasquez[346]	1	0	0	0	0	0	1	Low	Cross
Verbestel[314]	1	1	0	1	0	1	4	Moderate	Cross
Vorwerg[315]	1	1	0	0	0	1	3	Moderate	Cross
Wijtzes[376]	0	0	1	0	0	1	2	Low	Cross
Williams[63]	1	1	0	1	0	0	3	Moderate	Cross
Worobey[348]	1	0	0	0	0	0	1	Low	Cross
Yamamoto[349]	1	1	0	0	0	0	2	Low	Cross
Zecevic[316]	1	1	0	1	0	1	4	Moderate	Cross
Total	122(93%)	103(79%)	25(19%)	38(29%)	0(0%)	90(69%)		Low=43(33%) Mod=78(60%) High = 9(7%)	

(Q1) Did the study describe the participant eligibility criteria?
(Q2) Were the participants randomly selected?
(Q3) Did the study report the sources and details of physical activity assessment clearly and did the instruments have acceptable reliability for the specific age group (an intra-class correlation coefficient .70 or Pearson correlation .80 was considered acceptable)?
(Q4) Did the study report the sources and details of assessment of biological, demographic, psychological and environmental correlates and did all of the methods have acceptable reliability (e.g. parents physical activity, green space)?
(Q5) Did the study report a power calculation and was the study adequately powered to detect hypothesized relationships?
(Q6) Did the study report the numbers of participants who completed each of the different measures?
*Level of Quality: 5 – 6 = High, 4 – 3 = Moderate, 2 – 0 = Low. Studies in **Bold** are high quality and/or are of prospective design,
** Cross = Cross-sectional, Inter -B= Intervention Baseline results, Pro = prospective study.

3.4.4. Description of Included Studies

A large number of studies were conducted in the USA (n=52, 40%). The age of participants within studies ranged from 0.5[292] to 5.95 years[291] (mean=4.3 years). Four studies (3%) investigated potential correlates of PA with infants, 35 (27%) with toddlers, and 92 (70%) with preschoolers. Sample sizes ranged from 20[268] to 10,694[262] (median=208). Studies investigated between one and 51[283] potential correlates (median=3).

Most studies (n=104, 80%) used objective measurements of PA, including: accelerometers (n=80, 6 determinant studies); direct observation (n=13, 2 determinant studies); pedometers (n=7); doubly labelled water (n=2), and heart rate monitoring (n=1). Twenty-four studies (1 determinant study) used parental proxy-report. Of the nine high quality studies, six (67%) used accelerometers,[130,255,263,265,266,364] one (11%) used doubly-labelled water,[264] one used proxy-report,[262] and one used accelerometer plus proxy-report.[257]

3.4.5. Demographic and biological variables

Thirty potential correlates of TPA were identified (Appendix 3.4), 10 of which were investigated ≥4 times (Table 3.2). Six high quality studies investigated differences of TPA by sex, and overall found boys to be more active than girls. Body mass index (5 high quality studies, 40% with negative associations) was found to be inconsistently associated with TPA. The strength of the associations/the presence of an association between sex, ethnicity and parental education and TPA varied between studies using objective and subjective measures of TPA. Nine potential determinants were identified for TPA (Table 3.2 and Appendix 3.5). The most frequently investigated potential determinants were sex (three studies) and age (four studies). All other variables were investigated once and showed no associations, apart from maternal depressive symptoms which showed a negative association with TPA.

A total of 19 potential demographic and biological correlates were investigated for associations with MVPA (Appendix 3.6), nine of which were investigated ≥4 times (Table 3.3). Four high quality studies (75%, strong association) investigated differences in MVPA by sex and found boys were significantly more active than girls. Seven potential determinants of MVPA were identified (Appendix 3.7): only sex was investigated more than once and the association inconsistently associated with MVPA (Table 3.3).

Fourteen potential demographic and biological correlates were investigated for associations with LPA (Appendix 3.8). Only three variables were investigated ≥4 times (Table 3.4); all had no association with LPA. Four potential demographic and biological variables (sex, ethnicity, BMI and parental education) were investigated as potential determinants of LPA (Appendix 3.9, Table 3.4) in one study.[153] The study found boys took part in significantly more LPA than girls; all other variables had no association with LPA.

Table 3.2. Summary of potential correlates and determinants of total physical activity.

	Related to TPA		Unrelated to TPA		
	Positive Association	Negative Association	No Association	Summary Code n/N (%)	
	No. Studies (No. HQ*)	No. Studies (No. HQ*)	No. Studies (No. HQ*)	Association[a]	High quality summary[b]
DEMOGRAPHIC AND BIOLOGICAL VARIABLES					
Correlates					
Age					
- Overall	14(2HQ)	5	20	**14/39 (36%) ?**	~
- Subjective	1	1	4	**1/6 (17%) ?**	~
- Objective	13 (2HQ)	4	16	**13/33 (39%) ?**	~
Sex (male)					
- Overall	42(6HQ)	~	35	42/77 (55%) ?	**6/6(100%)++**
- Subjective	5(1HQ)	~	10	**5/15 (33%) 0**	~
- Objective	37(5HQ)	~	25	37/62 (60%) +	**5/5(100%)++**
Ethnicity (white)					
- Overall	6	1	11(1HQ)	**6/18 (35%)?**	~
- Subjective	2	1	7(1HQ)	**1/10(10%) 0**	~
- Objective	4	0	4	**4/8 (50%) ?**	~
Socio-economic status					
- Overall	~	~	7	**0/7(0%) 0**	~
- Subjective	~	~	5(1HQ)	**0/5 (0%) 0**	~
- Objective	~	~	4	**0/4 (0%) 0**	~
Parental education					
- Overall	~	4(1HQ)	14	**4/18(22%) 0**	~
- Subjective	~	3(1HQ)	6	**3/8 (38%) ?**	~
- Objective	~	1	8	**1/9 (11%) 0**	~
Parental age					
- Overall	~	~	7	**0/7(0%) 0**	~
- Subjective	~	~	4(1HQ)	**0/4(0%) 0**	~
- Objective	~	~	3	**0/3(0%) 0**	~
Adiposity - Overall/Objective	1	3	4(1HQ)	**3/8(38%) 0**	~
Body Mass Index (BMI)					
- Overall	5(1HQ)	6(2HQ)	26(3HQ)	6/37(16%) 0	**2/5(40%) ?**
- Subjective	1(1HQ)	2(2HQ)	5	**2/8(25%) 0**	~
- Objective	4	4	21(2HQ)	**4/21(19%)0**	~
Gross Motor-Skills					
- Overall	9(2HQ)	1	13	**9/23(37%) ?**	~
- Subjective	1(1HQ)	~	~	1/1(100%) #	~
- Objective	8	1	13	**8/22(37%) ?**	~

Parents BMI					
- Overall	~	3	9	**3/12(25%) 0**	~
- Subjective	~	1	3	**1/4(25%) 0**	~
- Objective	~	2	6	**2/8(25%) 0**	~
Physical Health					
- Overall	~	3	7	**3/7(42%) ?**	~
- Subjective	~	~	4	**0/4(0%) 0**	~
- Objective	~	3	4	**3/7(43%) ?**	~
Family Structure					
- Overall	~	~	8	**0/8(0%) 0**	~
- Subjective	~	~	5	**0/5 (0%) 0**	~
- Objective	~	~	3	**0/3(0%) 0**	~
Siblings (no. and order)					
- Overall	2	~	6	**2/8(25%) 0**	~
- Subjective	0	~	2	**0/2 (0%) #**	~
- Objective	2	~	4	**2/6(33%) 0**	~
DEMOGRAPHIC AND BIOLOGICAL VARIABLES					
Determinants					
Age – Overall/Objective	1	2	1	**2/4(50%) ?**	~
Sex (male) – Overall/Objective	2	~	1	**2/3(66%) +**	~
Maternal depressive symptoms					
- Overall/Subjective	~	1	~	**1/1(100%) -**	~
Ethnicity (White)					
- Overall/Subjective	~	~	2	**0/2(0%) 0**	~
Parents education	~	~	1	**0/1(0%) 0**	~
Adiposity – Overall/Objective	~	~	1	**0/1(0%) 0**	~
Body Mass Index (BMI)					
- Overall/Subjective	~	~	2	**0/2(0%) 0**	~
Aerobic fitness					
- Overall/Subjective	~	~	1	**0/1(0%) 0**	~
Gross Motor-Skill Performance					
- Overall/Subjective	~	~	1	**0/1(0%) 0**	~
BEHAVIOURAL VARIABLES					
Correlates					
Television viewing (TV)					
- Overall	~	7(1HQ)	9	**7/16(44%) ?**	~
- Subjective	~	4(1HQ)	4	**4/8(50%) 0**	~
- Objective	~	3	5	**3/8(38%) 0**	~
SOCIAL AND CULTURAL VARIABLES					

Correlates					
Parental PA/family interactions					
- Overall	10(2HQ)	1	8	**10/17(59%) ?**	~
- Subjective	4(1HQ)	1	0	**4/5(80%) +**	~
- Objective	6(1HQ)	0	6	**6/12(50%) ?**	~
Parental support					~
- Overall	7	~	7	**7/14(50%)?**	~
- Subjective	5	~	0	**5/5(100%) +**	~
- Objective	2	~	7	**2/9(22%) 0**	
Parent(s) work status					
- Overall	2(2HQ)	4	9(3HQ)	4/15(27%) 0	**2/5(40%) ?**
- Subjective	1(1HQ)	2	5(3HQ)	**2/8(25%) 0**	1/4(25%)*
- Objective	1(1HQ)	2	4	**2/7(29%) 0**	~
Parenting Practices					
- Overall	4	1	14	**4/19(21%) 0**	~
- Subjective	2	~	4	**2/6(33%) 0**	~
- Objective	2	1	10	**2/13(15%) 0**	~
Parents perceptions and beliefs					
- Overall	5(1HQ)	~	4	**5/9(56%) ?**	~
- Subjective	4	~	4	**4/8(50%) ?**	~
- Objective	1	~	~	1/1(100)% #	~
Parents barriers					
- Overall	~	4	3	**4/7(57%) ?**	~
- Subjective	~	2	2	**2/4(50%) ?**	~
- Objective	~	2	1	2/3(66%) #	~
SOCIAL AND CULTURAL VARIABLES					
Determinants					
Parental PA/family interactions					
- Overall/Objective	1(1HQ)	~	5(1HQ)	**1/6(20%) 0**	~
Parental PA knowledge					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Parental PA views					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Parental PA optimism					
- Overall/Objective	1	~	2	**1/3(33%) 0**	~
Parental PA self-efficacy					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Parental PA future expectations					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Parental floor concerns					

- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Parental TV knowledge					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Parental TV use					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Parental TV self-efficacy					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Parental screen time					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Time spent playing outside with adults					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Tummy time					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Time spent on the floor					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Time spent playing with parent					
- Overall/Objective	3	~	1	**3/4(75%) +**	~
Time spent playing with peers similar age					
- Overall/Objective	~	1	4	**1/5(20%) 0**	~
Time spent with older toddlers or children					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
PHYSICAL ENVIRONMENTAL VARIABLES					
Correlates					
Time outdoors/in play spaces					
- Overall	7	~	1	**7/8(88%) +**	~
- Subjective	-	~	1	**0/1(0%)** #	~
- Objective	7	~	~	**7/7(100%) +**	~
Attend childcare					
- Overall	1	1	3	**1/4(20%) 0**	~
- Subjective	~	~	1	0/1(0%) #	~
- Objective	1	1	2	**1/4(25%)0**	~
Season (summer)					
- Overall	5	2(1HQ)	3(2HQ)	**5/10(50%) ?**	~
- Subjective	~	1	~	1/1(100%) #	~
- Objective	5	1(1HQ)	3(2HQ)	**5/9(56%) ?**	~

Weekday v weekend (weekday)					
- Overall	4	6	5(1HQ)	**6/15(33%) 0**	~
- Subjective	~	2	~	2/2(100%) #	~
- Objective	4	4	5(1HQ)	**4/13(31%) 0**	~
Time of day (afternoon)					
- Overall/Objective	2	~	2	2/4(50%) **?**	~
Month of PA data collected					
- Overall/Objective	1	~	5	1/6(17%) **0**	~
Frequency of visits to active play spaces (per week)					
- Overall/Objective	1	1	2	1/4(25%) *	~
Individual preschool					
- Overall	6(2HQ)	~	~	**6/6(100%) +**	~
- Subjective	1	~	~	1/1(100%) #	~
- Objective	5(2HQ)	~	~	**5/5(100%) +**	~
PHYSICAL ENVIRONMENTAL VARIABLES					
Determinants					
Time outdoors/in play spaces					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Play equipment at home					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~
Time of day (afternoon)					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
TV in home					
- Overall/Objective	~	~	2	**0/2(0%) 0**	~

HQ = High Quality Studies.
Overall = combined subjective and objective measures.
Subjective = Subjective outcome measure.
Objective = Objective outcome measure.
Overall/Objective = only objective measures were applied by studies exploring exposure.
Overall/Subjective = only subjective measures were applied by studies exploring exposure.
* = All associations were derived from the same study, so no code was awarded.
~ = No data.
a = association codes: 0 = no association, ? inconsistent, - negative , + positive, # = insufficient data to derive an association.
b = association codes for high quality studies (≥4 studies required): 00 = strong no association, ? inconsistent, ++ strong positive, -- strong negative.
Bold associations are the final grading for each exposure/variable.

Table 3.3. Summary of potential correlates and determinants of moderate-to-vigorous physical activity.

	Related to MVPA		Unrelated to MVPA		
	Positive Association	Negative Association	No Association	Summary Code	
	No. Studies(No. HQ*)	No. Studies(No. HQ*)	No. Studies(No. HQ*)	n/N (%) Association[a]	High quality summary[b]
DEMOGRAPHIC AND BIOLOGICAL VARIABLES - Correlates					
Age – Overall/Objective	8(1HQ)	2	11(1HQ)	**8/21(30%) ?**	~
Sex (male) – Overall/Objective	33(3HQ)	1	20(1HQ)	33/54(61%) +	**3/4(75%) ++**
Ethnicity (white)					
- Overall/Objective	1	2	4	**2/7(28%) 0**	~
Parental education					
- Overall/Objective	1	1	11(1HQ)	**1/13(8%) 0**	~
Adiposity – Overall/Objective	~	3	5	**3/8(38%) ?**	~
Body Mass Index (BMI)					
- Overall	3	4(1HQ)	23(1HQ)	**4/30(14%) 0**	~
- Subjective	~	~	1	**0/1(0%) #**	~
- Objective	3	4(1HQ)	22	**4/29(14%) 0**	~
Gross Motor-Skills					
- Overall/Objective	11	2	13	**11/26(42%) ?**	~
Parents BMI					~
- Overall/Objective	~	1	6	**1/7(14%) 0**	
Physical Health					
- Overall	1	4	4	**4/9(44%) ?**	~
- Subjective	~	~	1	**0/1(0%) #**	~
- Objective	1	4	3	**4/8(50%) ?**	~
DEMOGRAPHIC AND BIOLOGICAL VARIABLES -Determinants					
Sex (male) - Overall/Objective	1	1	2	**1/2(50%) ?**	~
Ethnicity(white)					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Parents education (degree) - Overall/Objective	~	~	1	**0/1(0%) 0**	~
Adiposity - Overall/Objective	~	~	1	**0/1(0%) 0**	~
Body Mass Index (BMI)					

- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Aerobic fitness					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Gross motor-skills					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
BEHAVIOURAL VARIABLES - Correlates					
Television viewing (TV)					
- Overall	1	1	2	**1/4(25%) 0**	~
- Subjective	~	~	1	**0/1 (0%) #**	~
- Objective	1	1	1	**1/3 (33%) #**	~
SOCIAL AND CULTURAL VARIABLES Correlates					
Parental PA/family interactions - Overall/Objective	4(1HQ)	~	4(1HQ)	**4/8(50%) ?**	~
Parent(s) work status					
- Overall/Objective	3		3	**3/6(50%) ?**	~
PHYSICAL ENVIRONMENTAL VARIABLES - Correlates					
Time outdoors/in play spaces - Overall/Objective	2	1	3	**2/6(33%) 0**	~
Attend childcare centre					
- Overall/Objective	2	~	3	**2/5(40%) ?**	~
Season (summer)					
- Overall/Objective	3	1	4	**3/8(38%) ?**	~
Weekday v weekend (weekday) - Overall/Objective	2	~	4	**2/6(33%) ?**	~
Individual preschool					
- Overall/Objective	3	~	1	**3/4(75%) +**	~
PHYSICAL ENVIRONMENTAL VARIABLES - Determinants					
Hours spent at preschool					
- Overall/Objective			1	**0/1(0%) 0**	~

HQ = High Quality Studies.
Overall = combined subjective and objective measures.
Subjective = Subjective outcome measure.
Objective = Objective outcome measure.
Overall/Objective = only objective measures were applied by studies exploring exposure.
Overall/Subjective = only subjective measures were applied by studies exploring exposure.
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~ = No data.
a = association codes: 0 = no association, ? inconsistent, - negative , + positive, # = insufficient data to derive an association.
b = association codes for high quality studies (≥4 studies required): 00 = strong no association, ? inconsistent, ++ strong positive, -- strong negative. **Bold** associations are the final grading for each exposure/variable.

Table 3.4. Summary of potential correlates and determinants of light physical activity.

	Related to LPA		Unrelated to LPA		
	Positive Association	Negative Association	No Association	Summary Code	
				n/N (%)	
	No. Studies(No. HQ*)	No. Studies(No. HQ*)	No. Studies(No. HQ*)	Association[a]	High quality summary[b]
DEMOGRAPHIC AND BIOLOGICAL VARIABLES - Correlates					
Sex (male)					
- Overall	5	~	9	**5/14(35%) 0**	~
- Subjective	~	~	1	**0/1(0%) #**	~
- Objective	5	~	8	**5/13(38%) ?**	~
Parental education					
- Overall/Objective	~	~	5	**0/5(0%) 0**	~
Body Mass Index (BMI) - Overall/Objective	~	~	7	**0/7(0%) 0**	~
DEMOGRAPHIC AND BIOLOGICAL VARIABLES - Determinants					
Sex (male)					
- Overall/Objective	1	~	~	**1/1(100%) +**	~
Parental education					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
Body Mass Index (BMI) - Overall/Objective	~	~	1	**0/1(0%) 0**	~
Ethnicity(white)					
- Overall/Objective	~	~	1	**0/1(0%) 0**	~
PHYSICAL ENVIRONMENT VARIABLES - Determinants					
Hours spent at preschool	~	~	1	**0/1(0%) 0**	~

HQ = High Quality Studies.
Overall = combined subjective and objective measures.
Subjective = Subjective outcome measure.
Objective = Objective outcome measure.
Overall/Objective = only objective measures were applied by studies exploring exposure.
Overall/Subjective = only subjective measures were applied by studies exploring exposure.
* = All associations were derived from the same study, so no code was awarded.
~ = No data.
a = association codes: 0 = no association, ? inconsistent, - negative , + positive, # = insufficient data to derive an association.
b = association codes for high quality studies (≥4 studies required): 00 = strong no association, ? inconsistent, ++ strong positive, -- strong negative.
Bold associations are the final grading for each exposure/variable.

3.4.6. Psychological, cognitive and emotional variables

Eleven potential psychological, cognitive and emotional correlates were investigated for associations with TPA, nine were investigated for associations with MVPA, and three were investigated for associations with LPA. None of the potential correlates were investigated frequently enough (≥4 times) to attribute a grade. No potential psychological determinants were identified for any PA category (Appendices 3.5, 3.7, 3.9).

3.4.7. Behavioural variables

Seven potential behavioural correlates were investigated for associations with TPA, eight were investigated for an association with MVPA, and one was investigated for an association with LPA (Appendices 3.4, 3.6, 3.8). The only variable to be investigated ≥4 times for both TPA and MVPA was TV viewing (Tables 3.3 and 3.4), which was classified as inconsistent for both types of PA. No potential behavioural determinants were found for any PA category.

3.4.8. Social and cultural variables

Twenty-seven potential social and cultural correlates were investigated for associations with TPA (Appendix 3.4); six were investigated ≥4 times (Table 3.2). Differences in associations of independent variables with subjectively and objectively measured TPA were found for parental PA (objective = ?; subjective = +) and parental support (objective = 0; subjective = +) (Table 3.2). There were no other associations with either objectively or subjectively measured TPA. Seventeen potential determinants of TPA were identified (Table 3.2, Appendix 3.5): parental PA had no association and time spent playing with parents (four models from one study,[154] 75% positive) had a positive association with TPA. No associations were found with the remaining potential determinants (Table 3.2, Appendix 3.5).

Thirty-seven potential social and cultural correlates were investigated for associations with MVPA (Appendix 3.6) and 18 for LPA (Appendix 3.8). Two variables (parental PA and parents work status) were classified as being inconsistent with MVPA (Table 3.4). For LPA no variables were investigated ≥4 times. No potential determinants of MVPA or LPA were identified.

3.4.9. Physical environment variables

Seventy-eight potential physical environment correlates (Appendix 3.4) were investigated for associations with TPA, eight were investigated ≥4 times (Table 3.2). Time outdoors in play spaces and the individual preschool attended were found to have positive associations. There were no differences between studies using subjective and objective measures. Four potential determinants were investigated (time outdoors, play equipment in the home, time of day, television in the home; Table 3.2) all showed no association.

Ninety potential physical environment correlates were investigated for associations with MVPA (Appendix 3.6). Five variables were investigated ≥4 times (Table 3.3). The individual preschool/childcare setting (type: faith, private, state run) was positively associated with MVPA (four studies, 75%), while the amount of time spent outdoors in play spaces had no association (six studies, 33%) with MVPA. Only one potential determinant of MVPA was investigated (Table 3.3): the number of hours a child spent at preschool was found to have no association with MVPA. No high quality studies investigated any potential physical environment correlates or determinants of MVPA.

Ten potential physical environment correlates were investigated for association with LPA (Appendix 3.8). No variables were investigated ≥4 times. One potential determinant of LPA (hours spent at preschool) was identified and showed no association (Table 3.4, Appendix 3.9).

3.5. Discussion

This systematic review identified a large number of observational studies that examined the correlates and determinants of PA in the early years. Few studies were of high quality and the number of identified correlates and determinants identified was small. All correlates and determinants found for each of the PA intensities (TPA, MVPA and LPA) were either demographic and biological variables, social and cultural variables or physical environment variables. Boys were found to participate in more TPA, MVPA and LPA than girls. The correlates and determinants found can aid in identifying potential efficacious mediators for the use in interventions aiming to promote TPA, MVPA and LPA of children during the early years, which to date have had little effectiveness.[243]

To date, there have been two known systematic reviews conducted specifically within early years children.[83,84] Like the previous reviews,[83,84] this review reported findings according to an ecological model, to highlight different levels of influence on PA.[129,132] There are some similarities and differences between the previous and current reviews (e.g. sex, ethnicity and time-outdoors).[83,84] Review differences may be due to the current review including more published studies over a longer period of time (Bingham:1900-2014, Hinkley:1980-2007, De Craemer: 1990-2010) and applying a larger age range (Bingham: 0-6 years, Hinkley: 2-5 years; De Craemer: 3-6 years). Like Hinkley[84] for TPA and De Craemer[83] for MVPA, we found sex to be a correlate (with boys more active than girls). Furthermore, sex also was found to be a determinant of LPA, but not MVPA; however, this was based on a small number of studies. Given PA varies between the sexes across the life course, with males mostly being reported to be more active than females,[134] and correlates of PA differ between boys and girls during the early years,[283] identifying sex-specific strategies to increase PA in future interventions is recommended. The necessity for sex-specific strategies is further strengthened by higher obesity prevalence in girls throughout childhood.[59,66,211]

Like Hinkley[84], it was found time spent outdoors in play spaces was positively correlated with TPA, but it was not found to be a determinant (2 studies). It is unclear if young children are more active outside because specific outdoor environments may be more conducive to PA (e.g. green space, playgrounds, and rural/urban areas). This finding suggests that time spent outdoors in play spaces could be a suitable behaviour to target in future interventions promoting TPA. Interestingly, this review found no association between time outdoors and MVPA. This could be because young children may need specific support and encouragement from parents/adults to engage in more intensive activity.[114] Attendance at preschool/childcare was found to be a positive correlate of both MVPA and TPA. Studies exploring preschool/childcare (all cross-sectional) found more PA took place within faith-based and private preschools compared to government preschools.[265,302,328,348] The study authors[265,302,328,348] speculated this difference was because faith and private preschools had greater space for children to play actively. With many children attending preschool/day-care/nursery (48.5% of USA[377] and 64% of UK children[378]), and with those environments providing prime opportunities to influence behaviours, it is highly recommended more research is undertaken to clearly identify which characteristics of those environments are associated with children's PA.

This review is the first known to summarize the determinants of children's PA during the early years. Determinants are considered more valuable than correlates because they show associations over time and are from stronger study designs.[60] Only sex has been previously identified as a determinant of PA in childhood.[134] This review also found sex to be a determinant of TPA, and maternal depressive symptoms and the time a parent plays with their child were additionally identified as determinants. However, caution must be taken when interpreting these results due to the small number of studies (n=9) investigating determinants. Many of the potential determinants were investigated in only one study;[154] therefore, more high quality, longitudinal/prospective research is needed to consistently identify determinants and better inform interventions.

A benefit of the large number of studies included within this review is that the findings could be stratified by the type of measure used for PA (objective or subjective). Subjective and objective measures ultimately measure PA differently. Generally, larger errors exist with subjective measures which can falsely inflate the proportion of variance a variable can account for within the outcome (e.g. habitual PA). Despite these differences there were few differences found between the correlates of subjectively and objectively measured PA across most domains of the ecological model. This is an important finding as consistency between the measures strongly supports the direction (or lack thereof) of an association. However, different associations for sex, ethnicity, parental education, parental PA, physical health and parental support were found between objectively and subjectively measured PA. Since few high quality studies were identified and only one used both objective and subjective measures with the same sample[257] (measured tracking [age] no difference between measures was found), we cannot say whether the inconsistencies in associations were due to the way PA was measured or other inconsistencies between study methodologies. The majority of studies within this review did use objective measures. Future studies using both objective and subjective measures are warranted in order to further investigate differences between factor associations with PA, between measurement types.

Despite the large number of studies identified in the present review, few (n=9) were of high quality. It may be that it is the reporting of studies which is poor, rather than the study itself. Therefore, a recommendation from this review is that the STROBE guidelines[251] are followed when reporting studies to ensure necessary information is included. Improving the quality and reporting of future studies could lead to more consistency across studies and greater confidence in the identified correlates and determinants of PA.

3.5.1. Gaps in the Research

The studies reported in this review focused primarily upon potential demographic/biological and social/cultural correlates/determinants of PA. Future research needs to explore potential correlates across the whole spectrum of the ecological model within one study to clearly identify the relative influence of individual correlates/determinants within the broader context of children's lives. The majority of studies included in this review were conducted in high-income Anglo/European nations, with little research conducted in low- to middle-income countries. There was also little research conducted investigating and examining the differences in the correlates and determinants between ethnic groups, particularly WB and SA children, and only a small number of studies examined potential correlates and determinants in children aged two or younger (infants and toddlers).

3.5.2 Limitations

A limitation of this review is the small number of identified longitudinal studies, with findings largely based on cross-sectional research. Most peer-reviewed literature was published in English which means the exclusion of non-English publications may in part account for the lack of studies found in low- and middle-income countries. Another limitation of the current review and all other correlate and determinant reviews is assigning a binary yes/no correlate/determinant category to exposure variables. The whole area of PA research needs to report the individual variance each individual exposure variable has with PA, rather than stating whether an exposure variable is statistically significant or not. By doing this, a future review, similar to the present review, would become more informative for intervention designers and policy makers when deciding which correlates/determinants to target within future young children's PA interventions and programmes.

3.5.3. Conclusions

Although a large body of research investigating potential correlates/determinants of PA in the early years has been published, few studies are of high quality. Studies included in this review focused predominantly on demographic and biological, and social/cultural correlates and determinants. Future research should focus on: 1) improved reporting of measurement methods so study quality can be accurately assessed; 2) longitudinal/prospective studies to assess temporal associations (determinants); 3) additional ecological domains relevant for PA early in life (e.g., policies, macroeconomics), and 4) the inter-relationship of constructs within and between domains.

CHAPTER 4 – Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years.

The study in this chapter has been published in the Journal of Sport Sciences: Bingham DD, Costa S, Clemes SA, Routen AC, Moore HJ, Barber SE. Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years - a worked example following a stepped approach. *Journal of Sports Sciences*. 2016;43(20):2005-10.

4.i. Preface

Of the many findings reported in the systematic review in Chapter 2, the identifying of limited research examining the correlates of MVPA between ethnicities especially WB and SA young children, is a key finding the rest of thesis will explore. To add, because of the availability of comprehensive birth cohort data, including a proxy-report MVPA and ST questionnaire of two year old children living in a predominate bi-ethnic community (the city of Bradford, UK), an opportunity to address these research gaps was available. In order to pursue this opportunity an investigation of the validity and test re-test reliability of proxy-report MVPA questionnaire needed to take place, using accelerometry as the criterion measure. This chapter preluded the validity and reliability investigation (Chapter Five) in order to estimate a population specific accelerometry wear-time, to reliably estimate habitual PA levels of young children living in the city of Bradford.

4.1. Introduction

Physical inactivity is a leading cause of non-communicable diseases worldwide.[20] Although non-communicable diseases are rare among young children (< 5 years); it is during the early years that modifiable behaviours such as physical activity (PA) and sedentary time (ST) develop.[237] Young children's PA is difficult to measure due its intermittent and spontaneous nature.[196] Accelerometers provide a valid objective measure of young children's habitual PA/ ST.[185,197,299] Accelerometers detect and measure acceleration (rate of change of velocity over time) of the human body via piezoelectric transmitters.[193,195] Movement is measured by accelerometers via the units (counts) of the electrical signal caused by accelerative forces acting upon the piezoelectric transmitter.[195] Different models of accelerometers (uniaxial, biaxial, triaxial, omni-axial) can measure acceleration in different/multiple planes of movement;[193,195] but the real strength of accelerometers is the ability to measure the frequency, duration, intensity and bouts of PA with sensitivity (some models sample movement up to 100 hertz).[193,195] Although progress has been made towards understanding young children's PA and ST through accelerometry, a lack of consistency in its use is evident across the literature,[110,175] particularly regarding wear-time processing and inclusion criteria.[203-205,379]

Wear-time and its counter-part non-wear-time are two of the most important aspects of accelerometer measurement researchers must give full consideration to.[2,110,175] Once initialised accelerometers continually collect data even during periods when the monitor has been removed such as during sleep, naps, or water based activities (bathing, swimming bathing).[2,175,202] Sometimes it can be difficult to distinguish between non-wear time and sedentary behaviours (television viewing, sitting reading etc).[2,202] Wear time is the amount of time the accelerometer has been worn for, sufficient wear time durations are required in order for participants to have enough data to provide a reliable measure of habitual PA.[2,193] Researchers apply parameters, often subjectively, or derived from other samples, to their data including: the minimum duration of a standard day, the minimum number of days required to reliably estimate habitual activity, the inclusion of a weekend-day and the exclusion of the first day of data (limiting potential reactivity).[380] The application of previously published wear/inclusion criteria derived from samples that differ (e.g. children from different geographical and cultural settings may have different PA/ST habits,[88,89] as well as different lengths and start/end of the time they are awake) from those being studied may lead to the unnecessary loss of participants and therefore statistical power if predefined criteria are not met.

4.2. Aims

This aims of this study were to 1) identify the wear-time criteria to reliably estimate habitual PA and ST levels of young children living in Bradford; 2) present the methods used as a worked example in a simple stepped-process to aid researchers when deciding on the number and type of days (weekday and/or weekend) of accelerometer data required to reliably estimate the habitual PA and ST of a sample of young children.

4.3. Methods

4.3.1. Participants and Settings

Participants were drawn from two separate studies run in the city of Bradford in the north of England: the Preschoolers in the Playground (PiP) study (n=216)[184,381] and a study examining the PA and ST of children taking part in a cohort study (n=83).[182] The studies' accelerometry protocols were identical, and therefore data were pooled, giving a combined sample of 299 children (2.93±0.59 years). The sample was composed of 152 boys (50.8%) and 147 girls (49.2%), 151 white British, 126 (50.5%) South Asian (42.1%) and 22 (7.4%) other ethnicities. Data were collected during the years of 2011-14. Institutional ethical approval was granted for both studies (PiP: NRES committee Yorkshire and the Humber [12/YH/0334]; Loughborough Universities ethics committee).

4.3.2. Procedure and Measurements

Participants wore an ActiGraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) for 7-8 consecutive days on the right hip during waking hours. In order to have enough battery life for 7-8 consecutive days, the sampling rate of 60 hertz was selected. Data were downloaded and initially processed in Actilife v6. The start of a day was recorded as the first consecutive minute of count data >0 counts. Days with <3 hours and >18 hours of wear-time were excluded.[205,382] Three or fewer hours of wear-time was deemed too little to provide a reliable indicator of daily behaviour. Similarly, a child at such a young age with greater than 18 hours of wear-time per day was deemed unrealistic. These cut-offs follow a recent study of 4 year olds where the average daily wear time was 14 hours/day.[59] A valid day was determined as 80% of the period during which 70% of the sample had recorded data (70/80 rule).[207,383] Non-wear-time was determined as ≥10 minutes of consecutive zero counts.[196] Raw count data was integrated into 5-second and 15-second epoch data to correspond with original calibration methods of the chosen intensity cut points: Costa Axis-1 [188] for ST (≤5 counts/5-second epoch) and total PA (TPA) (≥5 count/5–second epoch); Pate [197] for moderate-to-vigorous PA (MVPA) (≥420 counts/15–second epoch). Because two separate cut-points have been applied the proportions of each intensity will not add up to 100%.

4.3.3. Data analysis

To determine wear-time requirements for generation of reliable estimates of habitual PA/ST, a six-step process based upon previous analyses [182] was followed (Figure 4.1). Normality of all continuous data was checked with Shaprio-wilk test along with the viewing of histograms- weekday, weekend, single day data were all not normally distributed therefore non-parametric tests were run (Wilcoxon and Friedman). All analyses were conducted in SPSS (version 22). Alpha was set at p≤0.05 for all inferential tests.

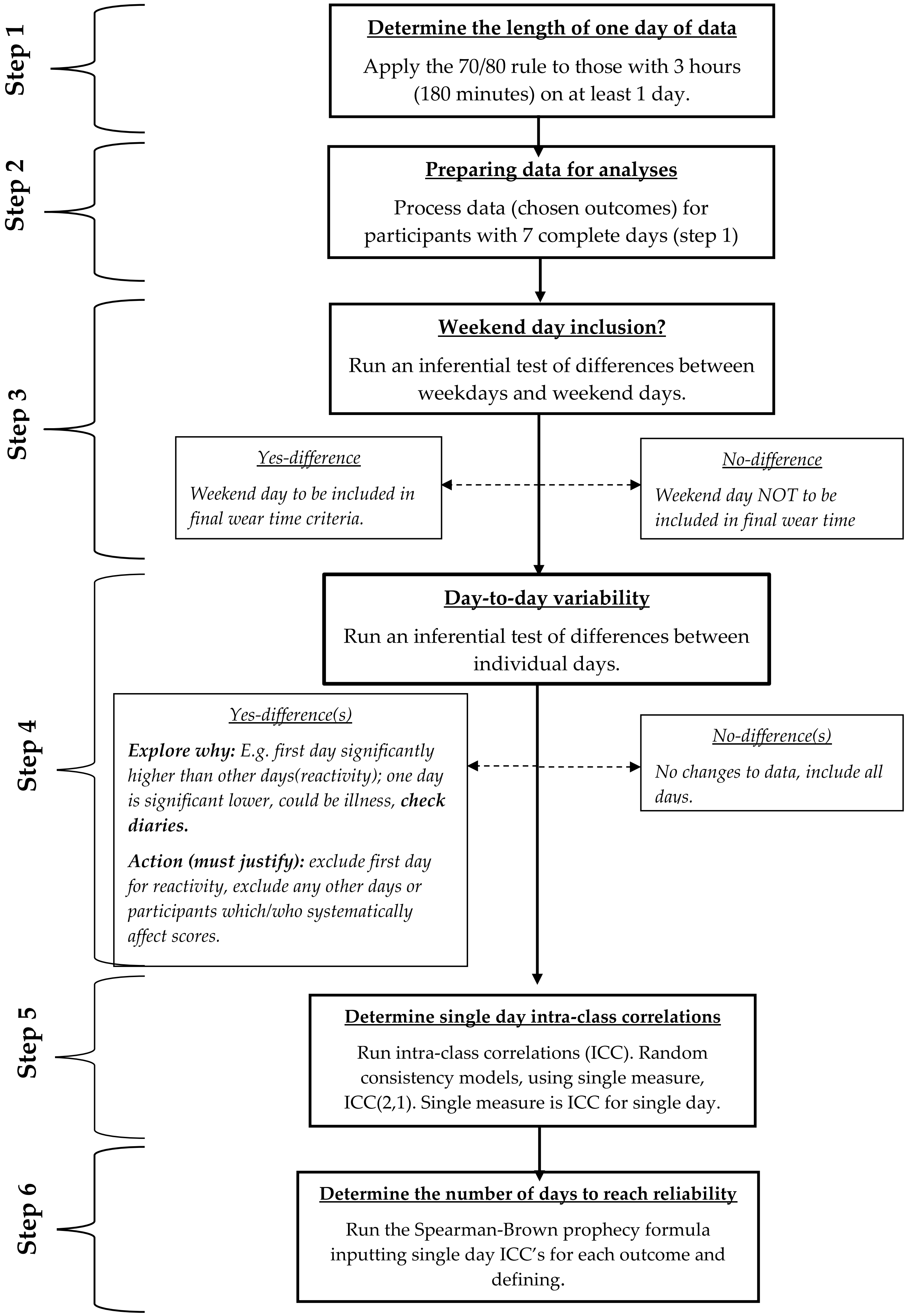

Figure 4.1: A six step process to calculate reliable accelerometer daily wear

Step 1: to calculate the minimum length of a required day, the 70/80 [207,383] rule was applied to children who had >3 hours and <18h data on at least one day.

Step 2: datasets with <7 complete days of data were excluded to eliminate potential confounding of missing days. Outcome variables of mean/median (based upon normal distribution) ST (5-second epochs), MVPA (15-second epochs) and TPA (5-second epochs); and percentages of wear-time in intensity categories (%ST, %MVPA, %TPA) were then generated (e.g. (100/daily wear-time)×mean minutes of intensity)). Percentage values were derived to control for possible confounding of wear-time.[382] Chi-square tests were also run to test if there were any demographic differences (sex, age and ethnicity) between participants who provided seven days of data and those that did not.

Step 3: paired students t-test's or Wilcoxon matched-paired tests assessed differences in mean/median time and proportion (%) time in SB/TPA/MVPA between weekdays and weekend-days. A significant difference between weekdays and weekend days determined if the inclusion of a weekend-day was required.

Step 4: to assess potential reactivity, one-way repeated measures ANOVAs or Friedman's two-way ANOVA by ranks assessed differences in all outcomes across the seven days.

Step 5: to assess reliability of estimates, intra-class correlations were calculated to establish the reliability of a single day (single measure). The single day measure has previously been used before and is comparable to all previous studies.[203,204,379,382] Due to the need to account for the variability between days (raters) and between participants, two-way random models (ICC[2,1]) were applied.[191,384] The repeatability of days did not need to be accounted for because no same day was repeated, therefore the purpose of the ICCs was to evaluate the consistency of accelerometer days.

Step 6: to calculate the number of days required to reach reliability coefficients of 0.7, 0.75 and 0.8, single-day ICCs were input into the Spearman-Brown prophecy formula.[385] To establish the minimum days needed for reliable estimates, all results were rounded up to full days (e.g. both 2.1 and 2.7 would be rounded up to 3 days).

4.4. Results

Step 1: in total, 282 (94%) participants had >3 hours and <18 hours of data on one day. Applying the 70/80 rule, 351.1 minutes (5.9 hours) was calculated to represent minimum wear time. This was then rounded up to give a daily minimum required wear-time of 360 minutes (6 hours).

Step 2: a total of 97 (32%) participants met the minimum daily wear-time of 351.1 minutes (Step 1) on seven consecutive days. Median daily (interquartile range (IQR)) wear was 646.5 (IQR: 591.1-700.5) mins/day. Participants spent 298.6 (IQR: 244.7-315.5) mins/day in TPA. As a proportion this was 43.9% (IQR: 39.2-48.0) of daily wear. Participants spent 362.8 (IQR: 315.2-409.9) mins/day in ST, which as a proportion of wear time was 56.6% (IQR: 52.4-61.5). For MVPA participants spent 69.50 (IQR: 55.2-84.9) mins/day of which was 23.3% (IQR:19.4-29.2) of daily wear. Chi-square tests found no difference in sex or ethnicity between participants who provided seven days of data and those that did not.

Steps 3 and 4: no statistically significant differences were observed between weekdays and weekend days (Table 4.1), or between the order of days (Table 4.2) for any of the outcome variables.

Table 4.1: Weekday verus weekend day accelerometer outcome variables.

	Median	IQR	z	p-value
MVPA-Weekday	69.7	50.5-85.9	-0.37	0.72
MVPA-Weekend	70.7	50.6-85.8		
%MVPA-Weekday	9.8	7.8-13.6	-1.70	0.10
%MVPA-Weekend	11.2	8.4-13.6		
TPA-Weekday	286.2	248.2-317.9	-1.26	0.21
TPA-Weekend	273.0	235.9-318.7		
%TPA-Weekday	43.5	38.8-47.7	-0.79	0.43
%TPA-Weekend	44.0	39.2-49.4		
ST-Weekday	365.3	313.9-414.5	-1.26	0.21
ST-Weekend	331.7	286.4-405.7		
%ST-Weekday	56.5	52.3-61.2	-0.79	0.43
%ST-Weekend	56.0	50.6-60.8		

MVPA = moderate to vigorous physical activity, TPA = total physical activity,
ST = sedentary time, % proportional value , IQR = Interquartile range, z = Wilcoxons Test statistic

Table 4.2: Day by day differences of accelerometer outcome variables

	Friedman $\chi 2$	p-value
MVPA (mins per day)	3.6	0.54
TPA (mins per day)	8.6	0.20
ST(mins per day)	8.6	0.20
MVPA%	5.2	0.54
TPA%	5.9	0.43
ST%	5.9	0.43

* = p ≤0.05

MVPA = moderate to vigorous physical activity, TPA = total physical activity,

ST = sedentary time, % proportional value

Table 4.3: Number of days required to reliably estimate accelerometer outcome variables.

Outcome (%)	single day ICC*	95% CL	Minimum days needed for **0.7 reliability**	Minimum days needed for **0.75 reliability**	Minimum days needed for **0.8 reliability**
MVPA (mins per day)	0.51	0.42-0.59	2.24	2.88	3.84
TPA (mins per day)	0.48	0.40-0.57	2.58	3.25	4.33
ST (mins per day)	0.48	0.40-0.57	2.58	3.25	4.33
MVPA%	0.53	0.43-0.61	2.15	2.77	3.69
TPA%	0.52	0.36-0.56	2.07	2.66	3.55
ST %	0.52	0.36-0.56	2.07	2.66	3.55

* Two-way Random ICC, consistency**, single.**

MVPA = moderate to vigorous physical activity, TPA = total physical activity , ST = sedentary time, % proportional value

Steps 5 and 6: Single day ICCs (2,1) ranged from 0.48 (TPA/ST) to 0.53 (%MVPA) (Table 4.3). From the Spearman-Brown prophecy formula, a minimum of three days was required to reach a reliability of 0.7 for all outcome variables (Table 4.3). To reach 0.75 three days were required for MVPA, MVPA%, TPA%, ST% and four days were required for TPA and ST (Table 4.3), and to reach 0.8, four days were required for MVPA, MVPA%, TPA%, ST% and five days for TPA and ST (Table 4.3).

4.5. Discussion

The present study is the first to investigate wear-time requirements using 5-second epochs (TPA and ST), which increases sensitivity when measuring young children's PA.[182,185,188] Following a seven day measurement protocol, this study found no evidence of reactivity nor differences between weekdays and weekend days, meaning a minimum of six hours of data on any three days was sufficient to reliably estimate (ICC=0.7)[379,382] young children's habitual time (and proportion of time) in TPA, ST and MVPA.

Similarly, six to eight hours of daily wear has been reported to be acceptable in previous studies within young children.[203,204,382] and is widely adopted in studies measuring PA during the early years.[175] Conversely, Penpraze[206] found and recommended a minimum of 10 hours of wear time is required for reliability of ICC=0.80 for young children. However, this study applied 60-second epochs, whereas other studies have utilised 15-second epochs.[203,204,382]

Like the current study, Hislop[204] found no differences in preschool children's activity between weekdays and weekend days, which agrees with studies from elsewhere.[114] As such, Hislop and co-workers advise that a sufficient number of any type of days could provide adequate reliability for young children's PA. Activity consistently differs between week and weekends in school-aged children and adolescents [211], for who the composition of valid days may be a more vital consideration, but some studies (Addy[203,]Hinkley[382]) have also observed type of day differences in young children's activity, and thus recommend weekend data be included in observations. Differences between studies could be due to how studies have dealt with non-wear time. The current study like Hinkley[205] applied the most conservative non-wear criteria of 10 minutes of consecutive zero counts. Hislop[204] applied a 20 minute criteria of zero counts whilst Penpraze[206] and Addy[203] applied a criteria of 60 minutes of consecutive zero counts. Currently there is no standard approach in defining non-wear time for young children.[202] This study applied the more conservative non-wear criteria because of the young age of participants. This age group are likely to exhibit spontaneous and intermittent behaviours and likely to move whilst being sedentary. Not moving for greater than 10 minutes at this age is a strong indicator of non-wear.[196]

Differences between studies could be due to cultural differences between samples. The current sample was derived from a deprived multi-ethnic community in northern England, which is socially, economically and environmentally different to that of Melbourne, Australia, [382] Columbia, USA[203] and multiple communities of Scotland.[204,206] Futhermore, not exploring the wear-time criteria for individual samples and applying criteria found reliable within different populations could lead to unnecessary reduction of sample size, statistical power and reliability. As an example: applying this study's criteria of six hours on three days on our sample led to a sample size of n=237 (79%); if applying six hours on three weekdays plus one weekend day[382] the sample would be reduced to n=199(67%). However, because there was no difference in PA/ST time between week and weekend-days this would have made little difference to the resulting average PA/ST estimates, but would have reduced sample size and power for further analyses.

4.5.1. Limitations

Like all studies this study is not without its limitations. This study followed widely used data processing techniques using cut-points, epochs and estimation of non-wear time. Studies are beginning to develop methods to process raw accelerometer data, including adopting different strategies of estimating non-wear time through moving windows approaches.[386] These techniques however are in their infancy and require a high level of expertise.[387] Current processing techniques will therefore still likely to be commonly applied in the coming years. As the aim of this study was to present a simple process to calculate reliable estimates of wear time, this study did not control for potential confounders such as sex, ethnicity, age, and BMI). Future studies should investigate the effect of confounding variables upon wear-time. Finally, only 32% of the sample provided 7 full days of accelerometer data, and were used in our illustrative example of the step-by-step approach which may raise a question over sampling bias.

4.5.2. Conclusion

This study identified that a minimum of six hours of data on any three days is sufficient to reliably estimate young childrens habitual PA who live in the city of Bradford. The methods presented in this chapter offer readers a practical worked example of how to derive sample specific wear-time criteria. Researchers in the future can follow these methods to calculate wear-time criteria for their individual samples, and have greater confidence that data sets are being used to their full capacity whilst also maintaining measurement reliability.

CHAPTER 5 – Reliability and Validity of the Early Years Physical Activity Questionnaire (EY-PAQ)

The study in this chapter has been published in Sports:

Bingham DD, Collings PJ, Clemes SA, Costa S, Santorelli G, Griffiths P, Barber SE. Reliability and validity of the early years physical activity questionnaire (EY-PAQ). *Sports*, 2016;4(2):30.

5.i. Preface

The study in Chapter 4 informed a reliable wear-time criterion to be applied for the use of accelerometry measurement of Bradford young children's PA and ST. This chapter applied this criterion in order to conduct a validation analysis of the Early Years Physical Activity Questionnaire – a proxy report questionnaire (in English and Urdu languages) which estimates young children's habitual MVPA and ST.

5.1. Introduction

The early years (ages 0-5) are vital for establishing healthy lifestyle behaviours including adequate levels of physical activity (PA) and low levels of sedentary time (ST), both of which can have immediate and long-term health impacts.[27,106,108] In the short term, total PA and moderate to vigorous physical activity (MVPA) both seem to be positively, and ST negatively, associated with multiple health outcomes in children (bone health, motor development, cardiovascular risk factors, cognitive development, psycho-social health and healthy adiposity).[27,388] In the long term, low PA and high ST are key risk factors for the onset of non-communicable diseases later in life (i.e. cardiovascular disease and type II diabetes).[20,223,224,389,390] These long-term influences may partly be explained by levels of PA and ST tracking over time.[118]

Objective monitoring tools, such as accelerometers, are becoming the first choice for field-based measures of PA and ST in young children.[185] Accelerometers can reliably and accurately measure the frequency, intensity and duration of young children's body movement within everyday settings.[175,197] Hnatiuk and colleagues [111] reviewed the results of studies measuring PA (n=40) and ST(n=31) in young children using accelerometers, and found that the daily proportion of time spent sedentary ranged from 34% to 94% whilst MVPA ranged from 2% to 41%. Although accelerometers are increasingly more common-place in published research,[175] like all methods accelerometers have limitations, including expense, participant burden, and the level of expertise required to process and analyse data.[185,196,391,392] These factors may preclude large-scale epidemiological studies of young children's (in)activity behaviours, which are particularly required within multi-ethnic and economically diverse populations, as there is a need to better understand health inequalities.[102-105]

In 2010 an epidemiological study called the Born in Bradford birth cohort study (BiB-1000, specifically) began investigating obesity risk factors for young children living in a multi-ethnic and economically diverse city.[393,394] At the time there were no available methods deemed appropriate to measure MVPA and ST in this population[394]; and as the use of an objective measure (such as an accelerometer) was not feasible due to the sample size (n = 1500), costs and relevant expertise, a new questionnaire was designed and implemented.

However, developing a new questionnaire may have had a practical use to enable analysis of the BiB1000 data set, but consideration for the use and purpose of a new questionnaire must be considered especially when prior to the current validation study, two new questionnaires were developed and validated to measure young children's PA. The two measures were the Preschool-age Children's Physical Activity Questionnaire (Pre-PAQ)[217] and Children's Physical Activity Questionnaire (C-PAQ)[218] The Pre-PAQ asks parents to recall specific intensities of activity such as walking at a slow pace, moderate pace and fast pace, which parents could struggle to distinguish. The C-PAQ asks parents to provide a total volume of time that their child has spent performing activities such as being at sport clubs, which would not be suitable for toddlers who spend much of their time with parents within the home. To add, both the Pre-PAQ and C-PAQ ask parents to distinguish differences between weekdays and weekends; and based upon the findings of Chapter 3 and 4 there appears to be no weekday weekend difference for Bradford young children, therefore such questions are not required. To add, neither the C-PAQ nor Pre-PAQ describe how to deal with questionnaire outliers (parent over reporting), or whether outliers were considered in data processing, meaning it is unknown whether extreme unrealistic answers were excluded or how they were excluded. Due to these reasons a new questionnaire with less participant burden was required. Having a new questionnaire found to be reliable and valid within a multi-cultural, bi-lingual, low socio-economic population will fill a gap left by a research area dominated by studies and tools measuring mainly White, English speaking middle-to-high income populations (see Chapter 3). Developing such a questionnaire would lead to a greater chance of collecting reliable and accurate epidemiological data within such communities. The Early Years Physical Activity Questionnaire (EY-PAQ) was developed to fill this gap, and measures the habitual PA and ST of young children in English and Urdu across multiple daily domains such as the home, transportation and wider community.

5.2. Aims

The aims of this study were to assess the EY-PAQ's test re-test reliability, and to determine its validity by comparing EY-PAQ data to accelerometry in a sample of young children from a deprived and multi-ethnic population, where English and Urdu are the predominant languages spoken.

5.3. Methods

5.3.1 Participants and Setting

The study sample consisted of young children aged 18 months to 48 months (4 years) and their parents who resided in the City of Bradford, UK. Parents were already recruited as part of a pilot cluster randomized controlled trial.[381] Bradford has an approximate population of 500,000 and is the sixth largest metropolitan area in England.[395] The city is also one of the most ethnically diverse and deprived areas in the UK.[395] Ethical approval for the study was granted by the Bradford Teaching

Hospitals Foundation Trust ethics committee, and informed consent was obtained from parents.

5.3.2 Procedure

Parents and children attended two appointments with a trained researcher. The first appointment included completion of the EY-PAQ, measurement of children's height and weight, and positioning of the Actigraph GT3X+ tri-axial accelerometer (ActiGraph, Pensacola, USA). Parents were instructed on how to fit the accelerometer to their child, which was attached around the waist over the right hip. They were also asked that their child wore the accelerometer during all waking hours for seven consecutive days. The second appointment took place approximately seven days later. Accelerometers were collected and the same researcher-parent pair completed the EY-PAQ.

5.3.3. Measures

5.3.3.1. The Early Years Physical Activity Questionnaire (EY-PAQ)

The EY-PAQ is a proxy-reported questionnaire that intends to quantify levels of habitual MVPA and ST in young children. The questionnaire is available in both English and transliterated Urdu (see Appendices 5.1. and 5.2.).[395] Parents were asked to report the frequency and duration of different MVPA and ST activities in which their child engaged during a typical week in the previous month. The activities for MVPA were: 1) playing actively in the house, 2) playing actively in the garden, 3) walking from place to place, 4) engaging in active play causing sweating and increased breathing, 5) playing in the park or playground, and 6) playing at indoor play facilities. The sedentary activities were: 1) colouring, drawing and craft, 2) sitting playing with toys, 3) watching TV/DVDS, 4) playing a non-active computer game, 5) sitting listening or singing to music, 6) reading or being read to, 7) travelling in a buggy/pushchair, 8) being carried while travelling, 9) travelling in the car, and 10) using public transport. A three stage process was used to calculate daily minutes of MVPA and ST. First, the duration of each activity reporting options were: 1) up to 15 mins/day, 2) 16-30 mins/day, 3) 31-60 mins/day, or 4) free-text for >60 mins/day) and this was multiplied by the frequency with which that activity occurred. A pragmatic approach was used with regards to the duration component; as parents tend to over-report PA and under-report ST[219], unless free-text responses exceeding 60 mins/day were reported, for the calculation of MVPA minimum reported durations were used (i.e. 1 min, 16 mins, or 31 mins) whereas for ST the higher values were used (i.e. 15 mins, 30 mins, and 60 mins). Second, the duration of each activity was summed in order to estimate daily minutes of MVPA and ST. Third, daily minutes of MVPA and ST were converted to the proportions, by dividing summed minutes in MVPA and ST, respectively, by 840 minutes (×100). Fourteen hours is typical of a waking day in preschool aged children[59], and is in line with sleep diary data that we have collected from similarly aged children from the source population (data not shown). Proportional values were used as the main outcomes in this study because parents completing the EY-PAQ considered the whole day in which an activity may have taken place. The accelerometer measured MVPA and ST only during the time the monitor was worn, which rarely reflected entire waking time; thus to account for disparities in the reference period, proportions of time were used.[396]

Proxy-reported questionnaires often find large variances in PA and ST due to reporting errors.[215] To objectively deal with assumed errors, the validity of the questionnaire was examined using 2 approaches, firstly by using all data and secondly only data falling within specific MVPA and ST boundaries (taken from the published literature [111]). The boundaries for MVPA were 2-41% and for ST 30-94%. The lower boundary for ST was reduced from the reported lower range of 34% to account for non-discretionary sedentary behaviours, such as bathroom or meal times, which accelerometry may have captured but the EY-PAQ did not pose questions about.

5.3.3.2. Accelerometry

The Actigraph GT3X+ is an accurate objective measure that has widely been used to measure young children's PA and ST.[188,196,203,284] It has been reported to be the favoured device to objectively measure PA amongst Bradford young children and their mothers.[190] For this study the accelerometer was set to record data at a sampling rate of 60 Hertz. Raw accelerometer data were downloaded and then transformed into both 5 second and 15 second epoch files. The choice of processing into two separate epochs was due to the original aim of using just 5 second epochs. Costa[182] found in a British sample of young children (age 2.9 years (SD 0.60)) both 10 second and 15 second epochs significantly underestimated ST. From these findings a new set of accelerometer cut-points, and the first to do so, were calibrated and validated using 5 second epochs.[188] The Costa cut-points were found to be accurate (criterion measure: direct observation [68]) in estimating young children's ST, but were found to be inaccurate in measuring MVPA. Therefore, an alternative cut-point was required to assess MVPA in this study. The Pate MVPA cut-points were chosen because they have been reported to be the most accurate and appropriate to estimate MVPA in young children.[156,170] As ST and MVPA were treated as independent behaviours the choice of epoch length was set in line with with the procedures of the original calibration studies that developed the ST (Costa: ≤ 5 counts per 5 seconds) and MVPA (Pate: 420 counts per 15 seconds) cut-points.[188,197] The minimum wear-time for inclusion in the analysis was at least 6 hours on any three days, which has been shown to provide reliable activity estimates (ICC=0.7) in the same population of children as the sample in the present study.[397] Non-wear time was defined as ≥10 minutes of consecutive zero counts.[196] In order to calculate proportion-values each child's recorded accelerometer MVPA and ST minutes, respectively, were divided by wear time, and then multiplied by 100.

5.3.4. Data analysis

Descriptive characteristics reported were different for each aspect of the study (ST validation, MVPA validation; test-retest reliability), therefore, descriptive characteristics are presented for all participants recruited to the study and then presented separately for each of the different analysis groups.

For the reliability analysis, test re-test reliability of the EY-PAQ for both MVPA and ST was assessed using a two-way random model intra-class correlation coefficient (ICC(2,1)) with 95% confidence intervals.[398] For the purposes of this study, coefficient values of 0.01 indicated 'poor' agreement, 0.01 to 0.20 'slight' agreement, 0.21 to 0.40 'fair' agreement, 0.41 to 0.60 'moderate' agreement, 0.61 to 0.80 'substantial' agreement and 0.81 to 1.00 'almost prefect' agreement.[399,400]

For the validity analysis, assessment of whether sex, ethnicity and language modified the relationships between the EY-PAQ and accelerometer MVPA and ST estimates was undertaken using multiple linear regression analyses. If any demographic variable was found to modify relationships, subsequent analyses were stratified by the influencing variable. All tests were conducted using the proportion data, with and without boundaries. Spearman rank correlations (rho) were applied to assess the correlations between the EY-PAQ and accelerometer data. Bland-Altman plots [401] were assembled to assess the agreement between EY-PAQ and accelerometry (before and after applying boundaries). Differences (error) between EY-PAQ and accelerometer estimates of MVPA and ST were calculated (error= EY-PAQ – Actigraph) and plotted against the mean MVPA and ST values of accelerometry and the EY-PAQ. The mean difference and direction of systematic error were examined through Pearson error correlations (error= x-axis, Actigraph= y-axis). Heteroscedasticity was examined using Breusch-Pagan-Cook/Weisburg Tests; where heteroscedasticity was present, heteroscedastic ratio limits of agreement (LOA) were calculated upon the log scale.[218,402]

All tests (reliability and validity) were conducted on proportions data. In order to give an easier understanding of results and enable comparisons with data from other published questionnaires, proportions were converted into minutes based upon a waking day of 840 minutes.[59] Analyses were conducted using SPSS for windows (version 22: IBM Corporation) and STATA (version 13), and alpha significance was defined as $p \leq 0.05$.

5.4. Results

The demographic characteristics of children are reported in Table 5.1. In total, 196 children and their parents took part in the validity study and 109 took part in the reliability study. A breakdown of the number of participants in each of the components of the study, including details of exclusions, has been outlined in Figure 5.1. The mean age was 3.2 years (SD ± 0.8), 50.5% were boys and 49% South Asian (Table 5.1). Most questionnaires were completed in English (79.6%) and with mothers (98%). There were no significant differences in the sex, ethnicity or age of participants included and those excluded in all aspects of the study. Multiple regression models found no significant interactions (sex, ethnicity and language) between the relationships of the EY-PAQ with accelerometry. Therefore, analyses were not stratified by sex, ethnicity or language.

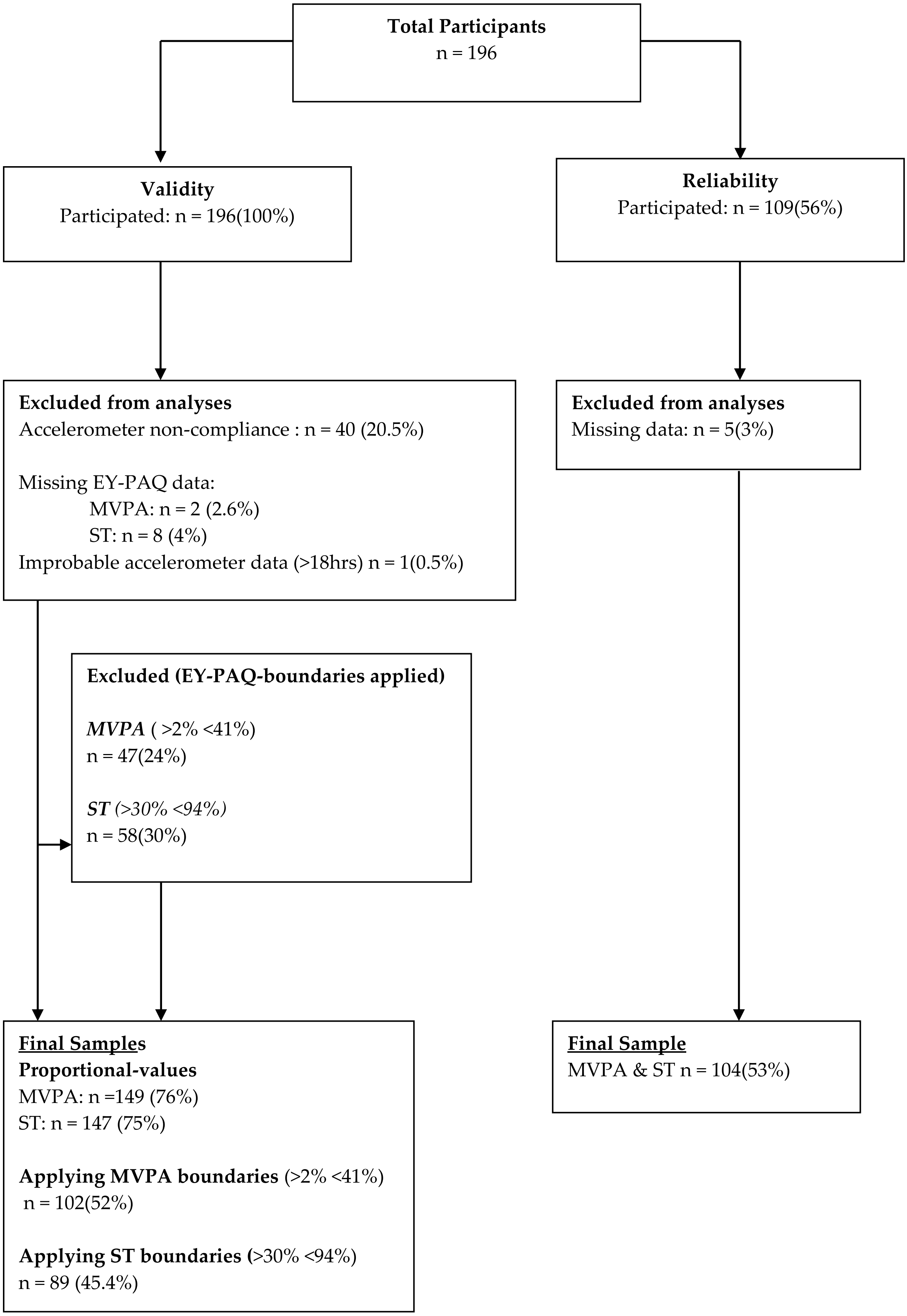

Figure 5.1: Flow diagram outlining the number of included and excluded participants for the validity and reliability analysis.

Table 5.1: Demographic characteristics of children within the different analyses of the study.

	All*		Validity**				Reliability	
	n = 196		ST (n =89)***		MVPA (n = 102)****		n 109	
	n(%)	Mean(SD)	n(%)	Mean(SD)	n(%)	Mean(SD)	n(%)	Mean(SD)
Sex								
Boys	99(50.5)		47(52.8)		56(54.9)		52(48)	
Girls	97(49.5)		42(47.2)		46(45.1)		57(53)	
Ethnicity								
White British	82(41.8)		30(33.7)		37(36.3)		33(30)	
South Asian	96(49)		52(58.4)		55(53.9)		67(62)	
Other	18(9.2)		7(7.9)		10(9.8)		9(8)	
Age								
Years		3.2(0.8)		3.2(0.8)		3.2(0.8)		3.3(0.8)
Language								
English	156(79.6)		69(77.5)		84(82.4)		82(75)	
Urdu	40(20.4)		20(22.5)		18(17.6)		27(25)	
EY-PAQ								
Proportion values			89(45.4)	47.0(13.6)	102(52)	21.2(11)		
Actigraph GT3X+								
Wear time (mins per day)			89(45.4)	594.8(100.7)	102(52)	582.1(127.3)		
Minutes per day			89(45.4)	344.1(88.0)	102(52)	118.4 (7.5)		
Proportion-values			89(45.4)	57.5(7.9)	102(52)	20.3(7.6)		

* Values presented are for validity analysis before the application of boundaries.
**Values presented are for the post application of boundaries within the validity analysis.
*** Costa cut-points (≤5 counts per 5 seconds)
**** Pate cut-points (≥420 counts per 15 seconds)

Table 5.2: Intraclass-correlations for moderate to vigorous physical activity (MVPA) and sedentary time (ST) as measured by the early years physical activity questionnaire (EY-PAQ).

	Reliability			
EY-PAQ Test1 v Test 2	N(%)	mean difference-mins per day (SD)	ICC(2,1)	95%Confidence Interval
MVPA	104(93.7)	25.5 (253.7)	0.35*	0.17-0.50
ST	104(93.7)	1.7 (196.6)	0.47*	0.3-0.61

*p≤0.05
**p≤0.05

Table 5.3: Validity of the early years physical activity questionnaire (EY-PAQ) compared to accelerometry.

	Validity						
EY-PAQ v Accelerometer	N(%)	*rho*	Mean daily minute difference [95% CI]	LOA†	Error Correlations (r)	Heteroskedasicity p-value	Ratio LOA†
MVPA: proportion-values	149(76.0)	0.03	106.3 [72.5, 140.2]	-303.7 – 516.4	-0.80*	0.94	1.20(×/÷ 10.6)
MVPA: Boundary applied >2%(16.8min)<41%(344.3min)#	102(52.0)	0.30*	7.1 [-12.3, 26.4]	-185.9 – 200.1	-0.37*	<0.01	1.03(×/÷ 5.8)
ST: proportion-values	147(75.0)	0.02	-160.0 [-189.1, -30.9]	-509.9 - 190.0	-0.67*	<0.01	1.72(×/÷ 3.6)
ST: Boundary applied >30%(252min)<94%(789.6min)#	89(45.4)	0.19	-87.5 [-117.6, -57.4]	-367.6 - 192.7	-0.50*	<0.01	1.26(×/÷ 1.9)

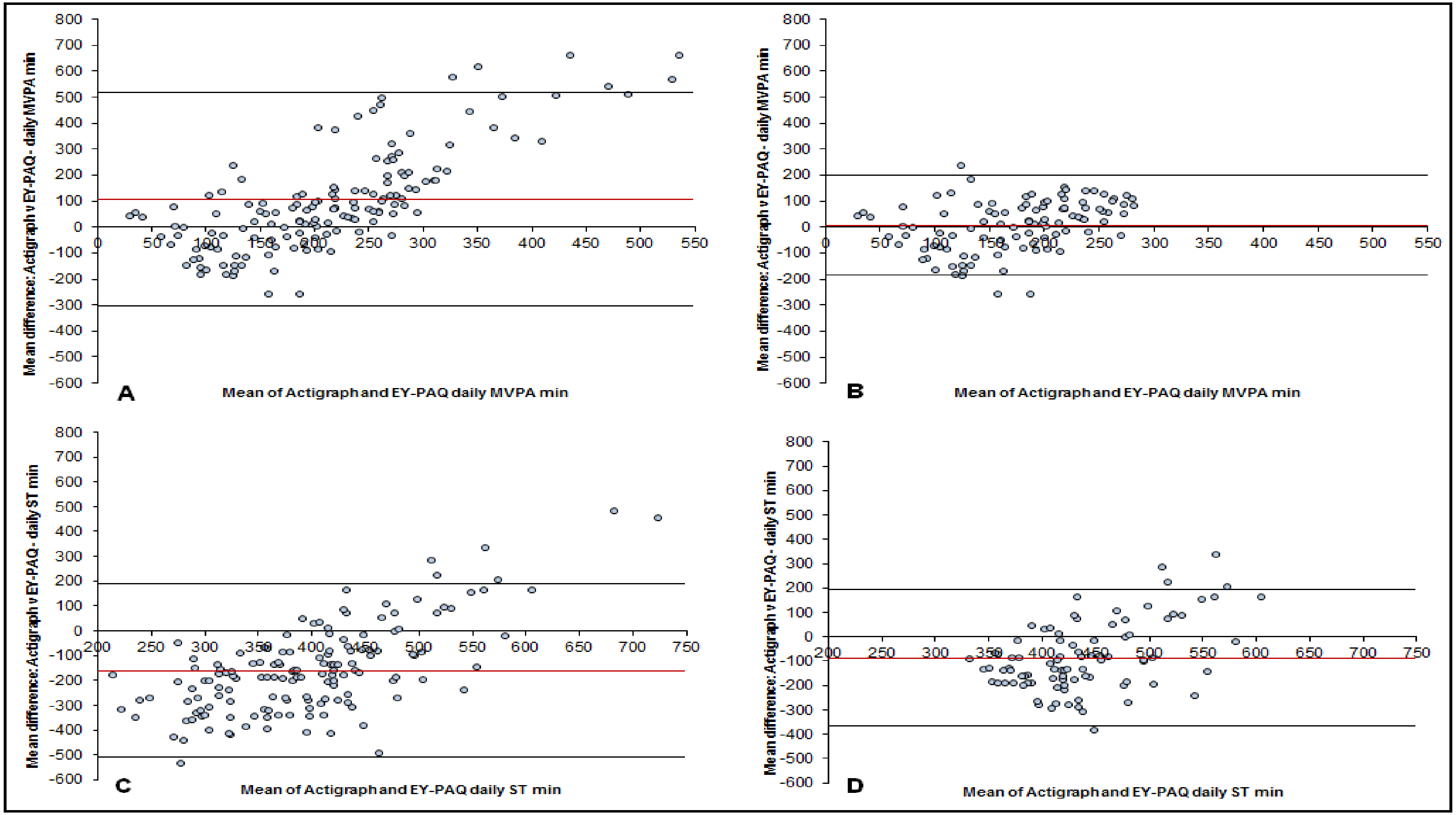

Figure 5.2: Bland –Altman plots for the difference between time spent in moderate to vigorous physical activity (MVPA) and sedentary time (ST) measured by accelerometry (Actigraph) and the Early Years Physical activity questionnaire (EY-PAQ); plotted against the mean average time spent in MVPA and ST measured by the Actigraph and EY-PAQ. **A**: MVPA plot for EY-PAQ-MVPA no boundaries applied. Mean difference: 106.3 mins/day; 95% limits of agreement (LOA): -303.7, +516.4. **B**: MVPA plot with EY-PAQ-MVPA boundaries applied. Mean difference: 7.1 mins/day; LOA: -185.9, +200.1. **C**: ST plot for EY-PAQ-ST no boundaries applied. Mean difference: -160.0 mins/day; LOA: -509.9, +190.0. **D**: ST plot with EY-PAQ-ST boundaries applied. Mean difference: -87.5 mins/day; LOA: -376.6, +192.7.

5.4.1. Reliability

The average number of days between the completion of the questionnaire at Test 1 and Test 2 was 7.4 days, ranging from 5 to 12 days.

Table 5.2 shows the results of the test re-test reliability analyses. There was fair agreement for test re-test reliability of MVPA measured by the EY-PAQ (ICC(2,1) = 0.35, 95% CI: 0.17-0.50)). For ST, there was moderate reliability (ICC(2,1) = 0.47, 95% CI: 0.30-0.61)).

5.4.2. Validity

Agreement between MVPA and ST estimated by the EY-PAQ and accelerometry are shown in Figure 5.2. For MVPA the mean difference was 7.1 mins/day (LOA: -185.9±200.1), and for ST the mean difference was -87.5 mins/day (LOA: -376.6±192.7).

The only significant correlation between the EY-PAQ and accelerometer was the proportion of time spent in MVPA after applying boundaries (Table 5.3). Error correlations for all values were found to be statistically significant (Table 5.3). The significant correlations highlight that systematic error existed. Breusch-Pagan / Cook-Weisburg tests found heteroscedasticity to be present ($p<0.05$) in the MVPA values and in the ST values. The MVPA mean bias on the ratio scale found MVPA was overestimated by 20%(1.20) and when the boundary-value was applied this was reduced to an overestimation of 3%(1.03). The ratio mean bias for ST found that it was overestimated by 72%(1.72) which was reduced to an overestimation of 26%(1.26) when the EY-PAQ boundaries were applied. The ratio-limits of agreement were wide for all results (Table 5.3).

5.5. Discussion

This study examined the reliability and validity of a new activity questionnaire (EY-PAQ) in a sample of young children from a diverse ethnic background where parents spoke either English or Urdu. Findings of the current study show the EY-PAQ had fair reliability for MVPA and moderate reliability for ST. The validity of the EY-PAQ was assessed against accelerometry. A small mean difference and significant correlation was found for MVPA after applying boundaries; leading to the EY-PAQ being an acceptable population method to measure young children's habitual MVPA. For ST, the mean difference was large and correlation coefficient non-significant. This was true even after applying boundary values, therefore the EY-PAQ is not a suitable population measure of ST.

The EY-PAQ is a new tool which measures the habitual levels of young children's MVPA and ST. Other similar tools which have been compared to accelerometry are the Preschool-age Physical Activity Questionnaire (Pre-PAQ) which was developed in Sydney, Australia and measures MVPA, light activity and ST,[219] and the Children's Physical Activity Questionnaire (C-PAQ) which was developed in Cambridge, UK and measures MVPA and total PA.[218] The test retest reliability of the MVPA component of the EY-PAQ was found to be fair and acceptable.[399,400] Sedentary time had a greater ICC value than MVPA (0.47 and 0.35). In comparison to other published questionnaires the EY-PAQ's ST ICC was similar to that of the Pre-PAQ's[219] (0.44). The EY-PAQ's MVPA reliability coefficient was lower than the Pre-PAQ's (0.54) and C-PAQ's (0.30).[218] It is perhaps unsurprising that reliability of all questionnaires were low compared to the 'almost perfect' criteria of ICC=0.8. Children's PA tends to be highly variable,[110] which means levels of MVPA and ST could be very different from one week to the next, thus affecting test re-test results.

With regards to validity, like the other questionnaires, differences in MVPA and ST were seen between the EY-PAQ and accelerometer. For MVPA, initial results of the

EY-PAQ validity assessment revealed larger error values in comparison to the Pre-PAQ[219] and C-PAQ.[218] The EY-PAQ overestimated MVPA by 12.6% (106.3 minutes/day), compared to the Pre-PAQ which overestimated MVPA by 50.1 minutes/day, while the CPAQ underestimated MVPA by -76.5 minutes. With regards to ST, the EY-PAQ underestimated daily sitting by -19% (160 minutes/day), which was a smaller difference to the Pre-PAQ's mean difference of -208.6 minutes/day. However, when the EY-PAQ boundaries were applied differences with accelerometry were reduced to 0.8% (7.1 minutes) for MVPA and -10.4% (87.5 minutes) for ST. Like the present study, Corder and colleagues[218] also assessed the heteroscedasticity of the C-PAQ and reported the anti-logged ratio limits of agreement. Results showed the CPAQ at best (depending upon accelerometer cut-points) underestimated MVPA by 32%. The anti-logged ratio limits of agreement of the EY-PAQ of agreement and ratio limits of agreement of the EY-PAQ, like the Pre-PAQ and CPAQ, were wide; however, the application of boundaries substantially reduced the limits of agreement between the EY-PAQ and accelerometer. Applying the EY-PAQ boundaries also improved the correlation coefficient between the two measures for both MVPA and ST. Before the application of boundaries the EY-PAQ had low, non-significant coefficients (MVPA [rho=0.03, $p \geq 0.05$ and ST [rho=0.02, $p \geq 0.05$]) when compared to the accelerometer. After applying boundaries the EY-PAQ's validity coefficients increased (MVPA: rho=0.30; ST=0.19). The MVPA coefficient was statistically significant, thus the EY-PAQ successfully ranked young children's MVPA after applying boundaries. The CPAQ was also found it could rank young children's MVPA (rho=0.42, $p \leq 0.05$). The EY-PAQ's ST coefficient after applying boundaries increased to 0.19 but was still statistical non-significant.

There are numerous reasons that could explain the differences in the reliability and validity coefficients seen between the EY-PAQ, CPAQ and Pre-PAQ. One reason is that the instruments vary in design and question structure. Another possible reason could be the differences in socio-demographic characteristics of the samples used in the three studies. The Pre-PAQ sample consisted of mainly high socio-economic status, white, English-speaking parents and children from Australia. The samples from both the EY-PAQ and C-PAQ validity studies were located in the UK, but the children in the current study were from communities of high deprivation, with a high ethnic mix and two different primary languages. Little is known about the sample of the C-PAQ study, other than the sample was from an affluent part of the UK (Cambridgeshire). Future studies should seek to validate multiple questionnaires in the same sample in order to test which of the questionnaires is the most reliable, valid and also feasible. The current study did explore the impact of demographic variables such as sex, ethnicity and language upon the linear relationship between the two measures. These variables were found not to impact the association between the EY-PAQ and accelerometry within the present sample.

The error for both MVPA and ST were lowest when mean accelerometer MVPA and ST were highest. This meant parents were more likely to over or under report MVPA and ST using the EY-PAQ when children's accelerometer-determined levels of MVPA and ST were low. This finding could be explained by the different measurement properties of a proxy-report questionnaire and accelerometer. Dependent upon the placement of the monitor, accelerometry constantly measures movements of the child when worn. However, proxy-report questionnaires are reliant upon what parents observe and remember when completing the questionnaire. Parents will not remember every 15 seconds of movement or sedentary time their young child has engaged in throughout the day; but the accelerometer (in the current study) recorded the child's movement (or lack thereof) every 15 seconds (the epoch length selected). Therefore, a difference between the two measurements was foreseeable. Despite the differences between the two types of methods, accelerometers are the most widely used comparison measure in which new self-report tools are validated against.[215] Because of the differences strong coefficients are seldom reported, with most self-reported validity coefficients with accelerometry ranging between 0.25-0.41.[215]

In the current study the inclusion of boundaries informed by data from a recent systematic review[111] did narrow the limits of agreement and greater accuracy was observed. However, it has to be noted this could lead to a possible exclusion of participants, and reduced sample sizes if the EY-PAQ was applied to future population-level studies. In this study the percentage of participant loss due to the application of boundaries was 23% (n=47) for MVPA and 30% (n = 58) for ST. Large scale studies using accelerometry also need to factor in participant loss due to the processing of data (e.g. not enough valid wear time). In comparison to large scale studies using accelerometry the EY-PAQ's participant loss was similar to that of the Healthy Active Preschool Years study (30%),[130] and less than half of the Millennium Cohort Study (children aged 7-8 years) (53%).[69] The use of the EY-PAQ and accelerometry share the limitation of possible sample size reduction; but the implementation of accelerometry and other objective measures are limited by the burden to participants (e.g. seven days wearing of monitor), level of expertise required to process data and financial costs, all of which do not apply to the EY-PAQ. The results of the current study indicate that the EY-PAQ has the smallest limits of agreement after the application of boundaries when measuring MVPA compared to other similar questionnaires'.[217,218]

The EY-PAQ is not suitable for measuring young children's ST. The Pre-PAQ also measures ST in young children, and like the EY-PAQ it was also found to be a weak measure. Reasons for inaccuracy could include that accelerometry would have likely detected most sedentary behaviours including those not measured by the EY-PAQ (e.g. bathroom and meal times). But also the two measures are measuring two different behaviours. The EY-PAQ is measuring the time and frequency parents report their child sits down doing different activities. Accelerometry measures ST by quantifying the absence of movement. Another reason for inaccuracy could be the design of the EY-PAQ's questions. By having smaller category options up to 60 minutes could lead to parents underreporting activities which children could spend greater than 60 minutes doing. Future research should investigate the validity and reliability parameters when using a different and more suitable comparison measure (e.g. inclinometers[403]) and adding more domains of ST within the EY-PAQ (e.g. time spent sitting while eating). Future development of the questions could be done to include categorical variables greater than the current options (e.g. 0-30 minutes, 30-60 minutes, 60-90 minutes).

A strength of the current study was the relatively large sample of children under the age of 5 years compared to previous validation studies in young children.[217,218] Furthermore, the EY-PAQ sample were from an ethnically diverse and bi-lingual population, thereby adding to the current measurement literature of early years children's PA and ST, which is heavily skewed by white English speaking samples.[217] However, results from the current study may not be generalisable to other populations, therefore additional validity and reliability studies using this new measure in different populations are required. Although a widely used objective field measure, the use of accelerometry as a comparable measure for ST was a limitation; they do not detect posture and only estimate ST through a lack of movement counts. Accelerometry therefore could be argued to be an unsuitable convergent measure for ST.[403] A possible valid direct objective measure of young children's standing and sitting is the Activpal inclinometer.[404] However, it must be noted that within a study examining the feasibility of the Activpal with Bradford young children and their parents, parents were concern about the possibility of causing discomfort because of the use of stickers in order to wear the Activpal.[180] But the Activpal has been successfully used within in other studies of young children,[405] therefore future research could look to test the EY-PAQ ST questions using the Activpal as a criterion measure.

5.5.1. Conclusion

The EY-PAQ has acceptable reliability and validity for measuring habitual MVPA of young children from a bi-lingual (English, Urdu), bi-ethnic (White British, South Asian) low socio-economic community. In situations when objective methods are not possible for measurement of MVPA in young children, the EY-PAQ may be a suitable alternative, but only if boundaries are applied. Having such a questionnaire means researchers can explore the early life determinants of MVPA in an ethnically diverse and low SES population, at a low cost. Such evidence will be useful for the development of tailored interventions, with better chances to decrease health inequalities in PA and related health outcomes in young children.

CHAPTER 6 – Levels and correlates of moderate to vigorous physical activity of two year old children from a bi-ethnic population.

The study in this chapter is in preparation to submit to the Journal of Physical Activity and Health:

Bingham DD, Clemes SA, Barber SE. The levels and correlates of moderate to vigorous physical activity of two year old children from a bi-ethnic population: A BiB1000 study. Submission Summer 2017.

6.i. Preface

In chapter three, the systematic review conducted identified a number of studies (n=7) which as part of their analysis investigated whether differences in MVPA occurred between young children of different ethnicities.[72] No differences in levels of MVPA between different ethnic groups were observed amongst the included studies. However, none of the studies had a sample size greater than 450, and no study investigated the differences in physical activity between White British and South Asian young children from the same geographical population. This chapter, using a large sample utilises the Early Years Physical Activity Questionnaire, found to have acceptable reliability and validity (Chapter 5)[406], to investigate the levels of daily MVPA and potential correlates of MVPA in two year old children living in a bi-ethnic highly deprived community.

6.1. Introduction

The early years are considered a critical period for the establishment of obesogenic behaviours that can track into adulthood.[237] One such obesogenic behaviour, PA, has been reported to track moderately throughout different stages of life.[121] A systematic review has reported TPA moderately tracks from the early years into middle childhood (0-5 years to 6-12 years).[118] In addition to the tracking of PA throughout childhood, regular PA (TPA) also has health benefits such as reduced adiposity[27,59], and leads to improved motor development[27], cardio-metabolic health[27], psycho-social health[27,54], bone and skeletal health[27] and cognitive development[27] in childhood. Tracking and health outcome association findings support the justification of promoting high levels of PA during the early years. Current guidelines for PA promote as much movement (any intensity of PA) as possible during the early years, with a minimum recommendation of 180 minutes of TPA to be undertaken daily.[106] It has been shown, using accelerometry, that the majority of early-years UK children meet these current recommendations.[114]

However, it has also been shown that children during the early years spend a high proportion of their total activity time in light intensity activities and ST as opposed to MVPA.[114,407] Understanding the correlates of MVPA is important for a number of reasons, including: MVPA during the early years has been associated with benefits to bone/skeletal development[245] adiposity[59] and metabolic status[66]; MVPA during the early years has been found to track into older childhood; MVPA is vital for health associations during middle to late childhood in the prevention of obesity and type two diabetes; and as no specific health associations have been identified with LPA, the promotion of MVPA during the early years could be seen as equally or perhaps more important than TPA.

The systematic review reported in Chapter 3 followed an ecological perspective.[128,129] Although a large number of studies were identified and synthesised, many of the studies had small sample sizes and either used poor methodologies or were poor in the reporting of methodological components.[72] This resulted in a small number of studies being graded as high quality. Studying correlates of PA is important as correlates research help generate hypotheses and identify possible moderators/target groups to target within future interventions.[60,408] The importance of correlates research is increased as previous intervention attempts to increase PA levels in children of all ages have generally been ineffective to date.[243,409] Possible reasons for this could be the lack of understanding of correlates, determinants and the possible lack of quality of previous research.[17,18,408] Therefore, despite the large amount of correlates research published previously, correlates research is still of great benefit as it is easy research to undertake and most importantly helps to generate hypotheses to better inform future interventions.

Ethnicity is an important potential correlate and moderator to explore because regular PA has protective effects on the onset of numerous chronic diseases (type II diabetes mellitus, cardio-vascular disease and obesity)[8]: for example South Asian

(SA) and other non-white ethnicities living in the UK have an increased risk of these chronic diseases in comparison with their fellow White British (WB) citizens.[91-100,103] Previous research has also strongly suggested intervention and primary prevention during the early years could be vital in reducing health disparities between ethnicities later on in life.[102-105] Across the PA literature it is reported that PA levels of British SA adults and school aged children are substantially lower than those of White British ethnicity.[87,90,410,411] In Chapter 3[72] it was found across the early years literature that TPA levels between ethnicities were inconclusive and no-associations with MVPA were found. However, studies identified were heavily skewed investigating mainly American populations (Hispanic, Black and White American populations) and children in the preschool years (3-6 years of age), and no study investigating ethnicity and MVPA had a sample size greater than 450 participants. There is currently no known research which has investigated differences in PA levels between White British and South Asian young children from the same geographical population. Such research is important as multiple large communities in the UK (e.g. Bradford, Birmingham, Leicester and London) have diverse populations with many languages spoken and different cultural practises.[20,21] In older children previous research has reported White British children have significantly greater levels of PA compared to their South Asian peers.[87-90] Furthermore, no known research investigating PA levels and correlates of an ethnically diverse population has been conducted using a large sample of young children, specifically toddlers (1-3 years of age).

In chapter 5 the EY-PAQ was found to have acceptable levels of reliability and validity to measure MVPA of young children living in the highly deprived, ethnically diverse and primarily bi-lingual UK city of Bradford.[406] The sub-cohort, of the Born in Bradford birth cohort[412,413], the BiB-1000 Study[38,39], included the EY-PAQ as one of the study's measures when the average age of the cohort was around 24 months. This data set offered the opportunity to examine the differences in

MVPA between White British and South Asian toddlers, and due to the large sample size investigate whether correlates of MVPA are different for different ethnicities.

6.2. Aim and Objectives

The aim of this study was to understand levels of MVPA and correlates of MVPA in a large sample of White British and South Asian toddlers from Bradford.

Because of the broad aim of the study specific objectives were followed in order to achieve the overall aim. The objectives of the study were to:

1. To report proxy (parental) reported MVPA levels of two year old children living in Bradford.
2. To explore the differences of MVPA between South Asian and White British two year old children.
3. To explore potential correlates of MVPA for Bradford two year old children based upon an ecological perspective.
4. To explore whether there are differences in the correlates of two year olds MVPA according to their ethnicity (WB & SA).

6.3. Methods

6.3.1. Setting

Participants were mothers and children residing in the city of Bradford. Bradford is located in the North of England, and has 528,200 residents (estimated in 2015), it is the fourth largest metropolitan district in the UK.[414] Many of the urban areas in Bradford are some of the most deprived in the UK, with 60% of babies being born into the poorest 20% of the population in England and Wales.[413,415] Bradford is ethnically diverse with a majority of people being of WB origin (63.9%) and a large minority being of SA origin (20.3%).[414] It is estimated 90% of the SA origin population stem from Pakistan,[413,416] which is the largest proportion of people with Pakistani origin in England.[414] The minority SA population are relatively younger and have higher fertility rates compared to the WB majority, this is believed to explain why 50% of babies born in Bradford are of SA (mostly Pakistani) origin.[39,40]

6.3.2. Participants, recruitment and procedure

Participants in the current study were all part of the Born in Bradford (BiB) birth cohort study, and specifically participating in a sub-sample study BiB1000[412,413] The BiB study is a longitudinal birth cohort examining the impact of genetic, psychological, social and environmental factors have on the health and well-being of Bradford mothers and children.[412,413] At 26-28 weeks gestation pregnant women waiting to have a routine glucose tolerance test at the Bradford Royal Infirmary were asked to be part of the Born in Bradford cohort. Recruitment took place between 2007-2010, and a total of 12,453 women during 13,776 pregnancies were recruited.[413]

A subsample of the BiB cohort, called BiB-1000, was established to investigate the patterns and aetiology of childhood obesity.[394] Recruitment of mothers and children took place between August 2008 and March 2009. BiB-1000 was a more intensive study with data being collected at five time points following on from the BiB cohort baseline data collection. The data collection time points took place when children were around 6, 12, 18, 24 and 36 months of age.[394,413] Data collection consisted of trained community researchers, who at each time point, conducted one interview with each mother in their homes. A total of 1916 mothers were eligible to be in the BiB1000 sub-study and 1,735 consented and were included.[394] For the purposes of the current cross-sectional study only data collected at the 24 months' time point were analysed. The reasoning for this was; one, more mothers took part and completed the outcome measure (EY-PAQ) at the 24 month time point compared to the 36 month time point; and two, a wider range of variables, covering more levels of the ecological model were collected at the 24 month time point compared to the 36 month time point. [39,40] Because of the greater sample size and wider range of variables collected the 24 months data were more suited from an ecological perspective which informed the cross-sectional analyses undertaken in the current study. All participants (mothers) gave informed consent, and ethical approval was granted by Bradford Teaching Hospitals National Health Service Trust Research Ethics Committee (Ref 07/H1302/112).

6.3.3. Outcome variable – moderate-to-vigorous physical activity

Daily minutes of MVPA were measured using the parental report questionnaire, the EY-PAQ. In chapter 5 it was reported that the test re-test reliability of the EY-PAQ was fair (ICC = 0.35) (CI: 0.17-0.50), and validity (vs accelerometry) was rho = 0.30, $p \leq 0.05$; mean error = 7.1 minutes (-185.9, 200.1), but only by applying proportional boundaries.[406] The EY-PAQ calculates an overall estimate of parent reported daily minutes of MVPA, via parents reporting the frequency and duration of different MVPA activities in which their child engages during a typical week over the previous month. Domains of activity were also collected and included and were 1) playing actively in the house (home-MVPA); 2) playing actively in the garden (garden-MVPA) 3) walking from place to place (walking-for-transport); 4) engaging in active play causing sweating and increased breathing (aka 'sweating-PA); 5) playing in the park or playground (park/playground-MVPA); and 6) playing at indoor play facilities (indoor play-MVPA). In order to maximise measurement accuracy the application of proportional boundaries was undertaken, as described in Chapter 5. Firstly, daily minutes of MVPA were converted into proportions based upon a standardised 840 minute waking day for this age group.[59] Secondly, participants with proportion values less than 2% or greater than 41% were excluded from the study, as values outside of these proportion boundaries would not be realistic and drastically decrease the accuracy of the EY-PAQ (see Chapter 5).[406] In order to give an easier understanding of results and enable comparisons with data from other published questionnaires, proportions were converted into minutes per day, which based upon a waking day of 840 minutes; this was applied in chapter 5.[59]

6.3.4. Potential correlates/ exposure variables

A total of 70 variables were examined as potential correlates. The rationale for selecting a large number of exposure variables (n=70) was because many of the exposure variables measured in the BiB1000 set have never been utilised before (as found in Chapter 3-systematic review), and due to the large sample size of the BiB1000 data set, a large number of these new exposure variables could be utilised within regression models. The 70 variables, following the ecological model, covered the levels of demographic and biological (e.g. age, sex, child's health, living status, index of multiple deprivation), behavioural (e.g. sleep time, TV and dvd viewing) social and cultural (e.g. mothers physical activity, barriers [weather, cost], parenting/household practices [TV at meal times, bed at a regular time] and environmental variables (e.g. attend preschool/nursery, number of passive or active toys the home, season). The full questionnaire used during the 24 month period can be found at http://www.borninbradford.nhs.uk/research-scientific/general-study-documentation-and-questionnaires-2/.

6.3.5. Data Analysis

For all continuous variables histograms were viewed along with skewness and kurtosis statistics. If any variables were not normally distributed or violated any of the assumptions for parametric tests across the different analyses, variables were rectified using natural logarithmic transformations and assumptions were tested again.

Independent t-tests or chi-square tests were conducted to test whether there were significant differences ($p \leq 0.05$) in demographic variables between children with or without valid EY-PAQ data. These tests were also applied to test for the presence of any demographic differences between WB children and SA children with valid EY-PAQ data.

Univariate linear regression model accounting for sex, age, language and season were conducted to examine the differences between WB and SA children's proxy reported average daily minutes of MVPA, and the proportion of time spent in MVPA within each of the EY-PAQ's domains.

To identify correlates of MVPA (for the whole sample, and separately for WB and SA children) a series of linear regression analyses were performed. Firstly, univariate associations between all potential correlates and daily MVPA were assessed. In order to protect against possible residual confounding of the final multiple regression model[417], the p-value for univariate regression models were set, as recommended by Maldonado and Greenland (1993)[418] at $p<.20$. Secondly, variables associated with MVPA with a p-value <0.20 in univariate models were grouped accordingly to groups/levels of the ecological model, and then included in hierarchical multivariable regression models in order to examine the percentage of variance accounted for in daily minutes of MVPA. Variables were entered in four steps: biological and demographic variables were entered first, followed by behavioural variables, social and cultural variables and finally environmental variables. Variance inflation factors in all multiple regression models were all <10 indicating multicollinearity was not a concern. In the multivariable models a + symbol was reported for a significant positive association and – symbol for a significant negative association. All analyses were conducted in Stata version 13.0.

6.4. Results

6.4.1. Descriptive statistics and valid EY-PAQ data

A total of 1228 mothers completed the BIB-1000 questionnaire at the 24 month time point (Table 6.1). After applying EY-PAQ boundaries a total of 837 children had valid MVPA data (68.2%), 391 (31.8%) mothers reported non-valid (out-side of boundaries) levels of MVPA for their children, and thus excluded from further analysis. Mean proxy-reported time in MVPA for the sample as a whole before application of boundaries was 234.2 (SD=194.5) minutes/day. Proxy-reported mean minutes of MVPA were significantly different ($p \leq 0.05$) between valid and non-valid EY-PAQ groups. Children with valid EY-PAQ data reportedly spent 18.8% (equating to 157.6 [SD=98.3) minutes/day) of their waking time in MVPA in comparison to children with invalid EY-PAQ data who reportedly spent 47.4% (equating to 398.2 [SD=242.2) minutes/day) in MVPA. The only other significant difference between groups was child's weight, with children in the non-valid group being 0.4kg heavier than children in the valid EY-PAQ group (Table 6.1).

Table 6.1: Descriptive statistics and demographic differences of children with valid EY-PAQ data versus children with non-valid EY-PAQ data.

Descriptive variables	Total (n = 1228)	Valid EY-PAQ (n = 837)*	Non-valid EY-PAQ (n = 391)***	p-value
MVPA (mins per day) #	234.2 (194.5)	157.6 (98.3)	398.2 (242.2)	0.00*
Sex ##				0.03
Boys	594 (48.4)	387 (46.2)	207 (52.9)	
Girls	634 (51.6)	450 (53.8)	184 (47.1)	
Ethnicity ##				0.47
White	481 (39.2)	319 (38.1)	136 (34.8)	
South Asian	685 (55.8)	457 (54.6)	228 (58.3)	
Other	62 (5.0)	61 (7.3)	27 (6.9)	
Childs Age (months) #	25.3 (0.9)	25.2 (0.9)	25.4 (1.0)	0.85
Weight (kg) #	12.4 (1.6)	12.3 (1.6)	12.7 (1.7)	0.01*
Height (cm) #	86.3 (5.4)	86.2 (4.9)	86.7 (6.1)	0.23
Body Mass Index (kg/cm2) #	16.6 (1.6)	16.7 (1.6)	16.6 (1.5)	0.75
Index of Multiple Deprivation Score#	42.5 (17.9)	42.3 (18.1)	43.2 (17.5)	0.41
Mother Education##				0.58
Higher than A level	296 (24.1)	193 (23.1)	103 (26.3)	
A-level or same	114 (9.3)	74 (8.8)	40 (10.2)	
5 GCSE	387 (31.5)	273 (32.6)	114 (29.2)	
< 5 GCSE	288 (23.5)	198 (23.7)	90 (23.0)	
Other	143 (11.6)	99 (11.8)	44 (11.3)	
Mothers Language ##				0.11
English	981 (79.9)	683 (81.6)	298 (76.2)	
Urdu	245 (20.0)	152 (18.2)	93 (23.8)	
Mirpuri	1 (0.1)	1 (0.1)	0 (0.0)	
Other	1 (0.1)	1 (0.1)	0 (0.0)	
Childs Health (mothers perception) ##				0.99
Excellent	227 (18.5)	154 (18.4)	73 (18.7)	
Very Good	452 (36.8)	310 (37.0)	142 (36.3)	
Good	483 (39.3)	329 (39.3)	154 (39.4)	
Fair	57 (4.6)	38 (4.5)	19 (4.9)	
Poor	9 (0.7)	6 (0.7)	3 (0.8)	
Parents Relationship Status##				0.85
Married	914 (74.4)	618 (73.8)	296 (75.7)	
Re-Married	1 (0.1)	1 (0.1)	0 (0)	
Single (never married)	286 (23.3)	200 (24.0)	86 (22.0)	
Separated (still legally married)	19 (1.5)	13 (1.6)	6 (1.5)	
Divorced	7 (0.6)	4 (0.35	4 (1.0)	
Missing Data	1 (0.1)	1 (0.1)	0 (0)	
Regular Childcare arrangements##				0.51
Yes	837 (68.2)	269 (32.1)	133 (34.0)	
No	391 (31.8)	568(67.9)	258 (66.0)	

$* = p \leq 0.05$

** = Included in analysis

*** = excluded in analysis

= Independent T-Test

= Chi-square test

Index of Multiple deprivation score (IMD) – each of England's Lower Super Output Areas are rated between 1 (most deprived) to 32,844 (least deprived).

6.4.2. Levels of daily moderate-to-vigorous physical activity

Table 6.2 shows the proxy-reported mean and median minutes and the proportion of minutes over a standardised waking day (840 minutes) children spent in MVPA; along with standardised minutes and proportion of time spent in MVPA for each domain of the EY-PAQ. For the whole sample children on average spent 18.8% of their standardised waking hours in MVPA (157.6 minutes, SD=98.3). The greatest contributor to daily MVPA was through MVPA accumulated inside the home (see Table 6.2).

Table 6.2: The levels of two year old childrens moderate to physical activity measured using the Early Years Physical Activity Questionnaire.

n=837	Mean min (SD)	Mean %	Median min (IQR)
Total MVPA	157.6 (98.3)	18.8*	154.7 (58.6-241.9)
Home MVPA	111.7 (90.7)	70.9**	120.0 (31.0-180.0)
Garden MVPA#	21.9 (36.3)	13.9**	8.9 (0.0-31.0)
Sweating PA#	3.3 (11.3)	2**	0.0 (0.0-0.4)
Walking MVPA#	9.1 (15.4)	5.8**	2.3 (0.4-16.0)
Park MVPA#	5.8 (8.1)	3.7**	2.3 (0.1-8.6)
Indoor Facilities MVPA#	5.8 (2.2)	3.7**	2.2 (0.0-8.6)

* mean proportion based upon waking day

** mean proportion based upon MVPA time

Not normally distributed

6.4.3. Ethnic differences of daily moderate-to-vigorous physical activity

Reported in Table 6.3 are the demographic differences between WB and SA children. Mothers education and index of multiple deprivation score were the only two significant demographic differences ($p \leq 0.05$) between the groups of WB (n=333) and SA (n=470) children (Table 6.3). Ethnic differences in the levels (in terms of minute/day) and proportions of time spent in MVPA are shown in Tables 4 and 5 respectively. There was no significant difference between WB and SA levels of overall MVPA (163.1 minutes v 152.4 minutes) (Table 6.4). However, linear regressions found SA children reportedly took part in significantly more minutes of MVPA in the home compared to WB children (Table 6.4), while WB children took part in significantly more walking for transportation (Table 6.4). Both WB and SA children were found to spend the majority of their reported time in daily MVPA inside the home (WB=57.5% of MVPA; SA=67.7%), followed by the garden (WB=15.8% of MVPA; SA=13.5%). As with the minute data, linear regressions found SA children spent proportionally more time in MVPA in the home compared to WB children, and WB children spent proportionally more time in MVPA walking for transportation than SA children.

Table 6.3: Descriptive statistics and demographic differences of White British and South Asian two year old children.

Descriptive variables	WB (n=333)	SA (n=470)	p-value
Sex #			0.57
Boys	169 (50.8)	229 (48.7)	
Girls	164 (49.2)	241 (51.3)	
Childs Age (months) ##	25.3 (0.92)	25.3 (0.04)	0.94
Weight (kg) ##	69.9 (16.6)	69.7 (16.0)	0.85
Height (cm) ##	86.2 (6.4)	86.9 (3.7)	0.12
Body Mass Index (kg/cm2) ##	16.6 (1.7)	16.7 (1.5)	0.56
Index of Multiple Deprivation Score##	36.7 (19.3)	47.0 (15.0)	0.01*
Mother Education #			0.01*
Higher than A level	83 (24.9)	103 (21.9)	
A-level or same	23 (6.9)	43 (9.1)	
5 GCSE	102 (30.6)	150 (31.9)	
< 5 GCSE	68 (20.4)	139 (7.4)	
Other	57 (17.1)	35 (7.4)	
Mothers Language #			0.17
English	333 (100)	373 (79.4)	
Urdu	0 (0)	97 (20.6)	
Childs Health (mothers perception) #			0.35
Excellent	63 (18.9)	86 (18.3)	
Very Good	132 (39.6)	170 (36.2)	
Good	117 (35.1)	194 (41.3)	
Fair	18 (5.4)	16 (3.4)	
Poor	3 (0.9)	4 (0.85)	
Parents Relationship Status #			0.26
Married	234 (70.3)	354 (75.6)	
Re-Married	0 (0)	1 (0.2)	
Single (never married)	94 (28.2)	103 (21.9)	
Separated (still legally married)	4 (1.2)	8 (1.7)	
Divorced	1 (0.3)	3 (0.6)	
Regular Childcare arrangements #			0.25
Yes	115 (34.5)	144 (30.6)	
No	218 (65.5)	326 (69.4)	

* = $p \leq 0.05$

= Chi-square test

= Independent T-Test

Index of Multiple deprivation score (IMD) – each of England's Lower Super Output Areas are rated between 1 (most deprived) to 32,844 (least deprived).

Table 6.4: The daily minutes of WB and SA children's MVPA and components of MVPA.

	White British (n=333)		South Asian (n = 470)		Linear Regression-MVPA MINS		Linear Regression-MVPA LOG#	
	Mean mins (SD)	Median mins (IQR)	Mean mins (SD)	Median mins (IQR)	β	95%CI-Variable	β	95%CI-Variable
Total MVPA	163.1 (94.2)	159.6 (70.9-245.3)	152.4 (101.7)	148.1 (49.7-240.0)	-10.8	-24.9, 3.3		
Home-MVPA	103.8 (82.24)	120.0 (31.0-180.0)	117.1 (96.4)	120.0 (31.0-180.0)	**13.3***	0.29, 26.3		
Garden-MVPA	27.0 (41.7)	12.9 (0.3-31.0)	17.7 (29.5)	6.9 (15-20.4)			0.2	-0.1, 0.4
Sweating-Activity	5.3 (14.2)	0.0 (0.0-4.4)	1.9 (9.1)	0.0 (0.0-0.0)			0.2	-0.3, 0.7
Walking-MVPA	13.7 (18.2)	9.1 (1.0-16.0)	6.0 (12.9)	1.0 (0.3-8.9)			**-0.3***	-0.1, - 0.5
Park-MVPA	5.8 (7.0)	4.3 (1.1-8.6)	5.3 (8.0)	2.2 (0.0-8.6)			0.1	-0.1, 0.3
Indoorplay-MVPA	7.5 (9.3)	4.3 (0.0-8.6)	4.5 (7.6)	0.0 (0.0-5.7)			0.1	-0.1, 0.4

Notes:
* p≤0.05
# Outcome variable was not normally distributed therefore regression analysis was run on successfully transformed log values (natural log).
60% of WB reported Sweating Q being 0
80% of SA reported Sweating Q being 0

Table 6.5: The proportion of WB and SA childrens MVPA which components of MVPA constitute.

	WB	SA	Linear Regression -MVPA MINS		Linear Regression -MVPA LOG#	
	Mean (SD)	Mean (SD)	β	95%CI-Variable	β	95%CI-Variable
Home-MVPA	57.5 (28.1)	67.7 (29.7)	**9.9***	5.7, 14.0		
Garden-MVPA	15.8 (19.5)	13.5 (19.4)			-0.1	-0.3, 0.1
Sweating-Activity	3.9 (10.3)	2.0 (7.8)			-0.1	-0.4, 0.3
Walking-MVPA	11.6 (14.0)	6.0 (12.5)			**-0.7***	-0.9, -0.5
Park-MVPA	4.7 (7.6)	4.8 (8.6)			0.2	-0.2, 0.3
Indoorplay-MVPA	6.5 (10.4)	6.0 (14.8)			0.2	-0.1, 0.4

Notes:
* p≤0.05
# Outcome variable was not normally distributed therefore regression analysis was run on successfully transformed log values (natural log).
60% of WB reported Sweating Q being 0
80% of SA reported Sweating Q being 0

6.4.4. The correlates of moderate-to-vigorous physical activity

Results of the univariate analyses are presented in Appendix 6. Reported in Tables 6.6, 6.7 and 6.8 are the findings of the hierarchical multiple regression models for the whole sample, WB children and SA children.

Simple linear regressions (Appendix 6) for the whole sample (n=837) found 21 variables to be statistically significant ($p<0.2$). The 21 variables along with language and BMI z-score were included in multiple linear regressions (Table 6.6). Of the 23 variables six were biological and demographical variables, two behavioural variables, eleven social and cultural variables and three environmental variables.

In the hierarchical regression models (Table 6.6), Model A (biological and demographic variables) accounted for 2.7% of the variance which was not statistically significant [$F(18,818) = 1.23$, $p \geq 0.05$]. Significant individual variables were child's health [excellent(reference) versus fair], which was positively associated (+) with MVPA, and mothers education [higher than A-level(reference) versus A-Levels) was negatively associated (-) with MVPA.

In step two (Model B) behavioural variables added a further 1.4% to the explained variance, which was not significant [$F(28,808) = 1.21$, $p \geq 0.05$]. The variable 'how often child watches TV/DVD at meal time' [never(reference) versus 1-3 times a month) was negatively associated with MVPA ($p \leq 0.05$).

In step three (model C) social and cultural variables added a further 5.9% to the explained variance, which was not statistically significant [$F(68,767) = 1.13$, $p \geq 0.05$]. Individual variables that were found to be significant were; 'child's weight compared to others' [about the same(reference) versus 'much heavier' (-)]; 'barrier for child to be active: the weather' [never(reference) versus 'once a week' (-)];

‘limited time watching TV/DVD’s in the last month’ [Everyday(reference) versus ‘5-6 times a week’ (+) and ‘once a week’ (+)].

In step four (Model D-final model) environmental variables added a further 3.6% of explained variance which lead to the model significantly accounting for 10% of the variance [$F(74,767) = 1.65$, $p \leq 0.01$]. Significant individual variables were mothers education [higher than A-level(reference) versus A-Levels, +); ‘limited time watching TV/DVD’s in the last month’ [Everyday(reference) versus ‘5-6 times a week’(+) 2-4 times a week (+) and ‘once a week’ (+)]; ‘barrier for child to be active: the weather’ [never(reference) versus ‘once a week’ (-)]; ‘number of active toys in the home’ (+); season [summer(reference) versus spring (-), autumn (-) and winter (-)].

Table 6.6: Multivariable associations of potential correlates with two year old children's MVPA.

POTENTIAL CORRELATES	All daily MVPA (n=837) Model A β (95% CI)	Model B β (95% CI)	Model C β (95% CI)	Model D β (95% CI)
BIOLOGICAL AND DEMOGRAPHICAL VARIABLES				
Sex				
Boys (Ref)				
Girls	-7.4 (-19.8, 4.9)	-7.1 (-19.6, 5.4)	-3.8 (-16.7, 9.2)	-6.7 (-19.4, 6.1)
Age (months)	3.0 (-3.5, 9.5)	2.7 (-3.9, 9.2)	3.0 (-3.7, 9.8)	-0.5 (-7.5, 6.5)
Ethnicity				
White (Ref)				
South Asian	-2.4 (-15.4, 10.7)	-1.1 (-14.7, 12.5)	2.0 (-12.1, 16.2)	1.1 (-12.3, 14.5)
Other	7.1 (-21.1, 35.2)	7.4 (-21.7, 36.4)	12.6 (-17.4, 42.5)	7.5 (-21.6, 36.6)
Child Health				
Excellent (Ref)				
Very Good	6.2 (-13.9, 26.2)	5.8 (-14.4, 26.1)	0.3 (-20.6, 21.2)	1.4 (-19.3, 22.1)
Good	14.9 (-5.7, 35.6)	13.5 (-7.5, 34.4)	7.9 (-14.0, 29.7)	8.4 (-13.2, 30.1)
Fair	**40.0 (5.0, 74.9)***	**37.7 (2.4, 73.0)***	28.1 (-9.2, 65.3)	20.4 (-16.1, 57.0)
Poor	58.2 (-12.6, 128.9)	54.6 (-16.5, 125.8)	52.4 (-21.3, 126.2)	56.6 (-16.5, 129.7)
Mother Health				
Excellent (Ref)				
Very Good	13.0 (-11.8, 37.8)	11.6 (-13.5, 36.7)	13.2 (-12.6, 39.1)	11.9 (-13.6, 37.4)
Good	-0.5 (-25.1, 24.0)	-2.3 (-27.2, 22.6)	-4.3 (-29.9, 21.3)	-8.5 (-34.0, 17.1)
Fair	-18.8 (-48.8, 11.2)	-21.0 (-51.3, 9.3)	-22.3 (-54.0, 9.5)	-25.3 (-56.5, 5.9)
Poor	-6.6 (-56.2, 43.0)	-9.3 (-59.0, 40.4)	-8.6 (-60.8, 43.5)	-10.1 (-61.4, 41.1)
BMIz Score	-0.2 (-8.9, 8.5)	0.1 (-8.7, 8.7)	0.2 (-8.4, 9.1)	0.2 (-9.1, 8.5)
Mothers education				
Higher than A-level (Ref)				
A-level	**-27.1 (-52.1, -2.2)***	**-26.8 (-51.8, -1.8)***	-22.4 (-48.8, 3.9)	**-27.2 (-53.3, -1.1)***
5 GCSE	-10.4 (-27.3, 6.5)	-10.8 (-27.8, 6.2)	-3.4 (-21.1, 14.3)	-5.4 (-22.9, 12.1)
<5 GCSE	-11.1 (-28.9, 6.7)	-12.3 (-30.2, 5.6)	-6.5 (-25.1, 12.0)	-8.4 (-26.7, 9.9)
Other	-19.9 (-41.8, 1.9)	-19.9 (-42.0, 2.2)	-15.0 (-37.8, 7.9)	-17.4 (-39.8, 5.0)
BEHAVIOURAL VARIABLES				
TV Screen Time before 6 pm on Weekend days				
None (Ref)				
<1 hour	~	2.1 (-16, 20.7)	3.1 (-16.3, 22.4)	0.5 (-18.4, 19.5)
1-2 hours	~	3.6 (-16.0, 23.1)	5.0 (-15.3, 25.3)	1.1 (-18.9, 21.0)
2-3 hours	~	-2.4 (-27.1, 22.3)	2.5 (-23.7, 28.6)	0.8 (-25.0, 26.7)
3-4 hours	~	-26.1 (-57.7, 5.5)	-27.6 (-60.4, 5.20	-28.3 (-60.6, 3.9)
>4 hours	~	4.9 (-37.0, 46.7)	8.7 (-35.5, 52.8)	5.8 (-36.8, 48.3)
How often child watched TV at meal times				
Never (Ref)	~			
1-3 times this month	~	**-23.4 (-48.0, -1.3)***	-24.9 (-50.6, 0.9)	-23.1 (-48.4, 2.1)
once a week	~	-22.4 (-48.4, 3.5)	-18.7 (-45.8, 8.5)	-18.6 (-45.4, 8.2)
2-4 times a week	~	-10.5 (-29.2, 8.2)	-14.1 (-33.7, 5.5)	-11.6 (-30.9, 7.7)
5-6 times a week	~	12.6 (-16.4, 41.6)	13.3 (-17.0, 43.5)	10.9 (-18.8, 40.6)
Everyday	~	-1.3 (-18.4, 15.7)	-3.9 (-21.9, 14.1)	-0.2 (-17.9, 17.4)
SOCIAL AND CULTURAL VARIABLES				
Mothers weekly VPA minutes	~	~	-0.1 (-0.2, 0.6)	-0.03 (-0.2, 0.1)
Childs weight compared to others				
About the same (Ref)				
much thinner	~	~	9.9 (-33.3, 53.1)	10.1 (-33.4, 53.7)
a little bit thinner	~	~	4.0 (-11.3, 19.2)	2.3 (-12.7, 17.2)
a little bit heavier	~	~	-0.3 (-19.4, 18.8)	0.3 (-18.5, 19.0)
much heavier	~	~	**-112.4 (-219.2, -5.7)***	-95.0 (-201.9, 11.90)
Perceptions of child being as active as peers				
Similarly active (Ref)				
generally more active	~	~	-1.4 (-42.2, 39.4)	6.2 (-7.2, 19.7)
generally less active	~	~	8.5 (-5.1, 22.0)	8.4 (-31.8, 48.5)

How often has mother or partner encouraged child to play active games in the last month				
Every day (Ref)				
5-6 times a week	~	~	-18.7 (-49.1, 11.8)	-16.6 (-46.8, 13.6)
2-4 times a week	~	~	1.8 (-18.3, 21.9)	1.1 (-18.7, 21.0)
once a week	~	~	-9.5 (-38.6, 19.6)	-4.0 (-32.5, 24.5)
1-3 times this month	~	~	1.3 (-48.8, 51.3)	5.0 (-46.6, 56.7)
Never	~	~	11.2 (-11.3, 33.7)	13.8 (-8.3, 35.9)
How often has mother or partner played an actively with child in the last month				
Every day (Ref)				
5-6 times a week	~	~	-4.4 (-30.5, 21.7)	-4.7 (-30.4, 21.1)
2-4 times a week	~	~	6.4 (-13.3, 26.1)	10.8 (-9.1, 30.7)
once a week	~	~	-14.4 (-42.1, 13.2)	-8.6 (-36.0, 18.8)
1-3 times this month	~	~	-8.0 (-48.1, 32.0)	-4.4 (-44.7, 35.8)
Never	~	~	1.8 (-30.0, 33.6)	3.0 (-29.3, 35.2)
How often mother or partner taken child to places to be physically active in the last month				
Every day (Ref)				
5-6 times a week	~	~	29.5 (-6.5, 65.5)	26.3 (-9.0, 61.6)
2-4 times a week	~	~	12.6 (-13.7, 39.0)	10.5 (-15.2, 36.2)
once a week	~	~	-1.4 (-29.2, 26.4)	-1.1 (-28.4, 26.2)
1-3 times this month	~	~	10.2 (-19.6, 40.0)	8.6 (-20.8, 38.0)
Never	~	~	15.0 (-18.1, 48.0)	18.6 (-14.1, 51.2)
Limited time watching TV/DVDs in the last month				
Every day (Ref)				
5-6 times a week	~	~	**38.4 (4.6, 72.2)***	**36.0 (3.3, 68.8)***
2-4 times a week	~	~	21.7 (-0.3, 43.7)	**22.7 (1.4, 44.0)***
once a week	~	~	**41.2 (13.1, 69.2)***	**39.1 (11.8, 66.4)***
1-3 times this month	~	~	12.8 (-24.1, 49.8)	16.2 (-20.0, 52.5)
Never	~	~	14.3 (-3.3, 32.0)	6.5 (-10.6, 23.7)
Limited time playing outside in the last month				
Never (ref)				
1-3 times this month	~	~	7.7 (-11.0, 26.3)	9.4 (-18.8, 37.7)
once a week	~	~	-5.2 (-30.9, 20.6)	-3.9 (-30.0, 22.2)
2-4 times a week	~	~	7.7 (-11.0, 26.3)	8.0 (-10.8, 26.8)
5-6 times a week	~	~	13.0 (-18.4, 44.3)	11.8 (-19.8, 43.2)
Everyday	~	~	5.9 (-13.5, 25.3)	6.7 (-12.7, 26.2)
Barrier for child to be active: weather				
Never (Ref)				
1-3 times this month	~	~	-8.0 (-27.6, 11.6)	-4.2 (-23.5, 15.1)
once a week	~	~	**-21.6 (-42.6, -0.6)***	**-20.8 (-41.4, -0.3)***
2-4 times a week	~	~	5.5 (-12.5, 23.5)	4.9 (-12.5, 22.3)
5-6 times a week	~	~	-11.8 (-48.8, 25.3)	-2.7 (-39.2, 33.8)
Everyday	~	~	-12.0 (-40.4, 16.4)	1.2 (-27.4, 29.8)
Parenting: feeling depressed				
None of the time (Ref)				
A little of the time	~	~	8.3 (-9.0, 25.5)	7.2 (-9.8, 24.2)
Some of the time	~	~	18.3 (-6.4, 42.9)	18.6 (-5.7, 43.0)
Most of the time	~	~	6.0 (-41.7, 53.7)	0.6 (-46.3, 47.4)
All of the time	~	~	12.5 (-52.1, 77.1)	15.8 (-47.5, 79.0)
Parenting: feeling hopelessness				
None of the time (Ref)				
A little of the time	~	~	3.2 (-17.6, 24.0)	5.4 (-15.2, 26.0)
Some of the time	~	~	0.5 (-25.6, 26.5)	0.6 (-25.4, 26.7)
Most of the time	~	~	-30.9 (-89.1, 27.3)	-15.6 (-73.5, 42.3)
All of the time	~	~	-69.3 (-169.9, 31.3)	-51.8 (-150.5, 46.9)
ENVIRONMENTAL VARIABLES				
Amount of time spent at nursery/preschool each week				

Do not attend (Ref)				
Part time	~	~	~	-15.4 (-32.7, 1.9)
Full time	~	~	~	-2.6 (-30.1, 24.8)
No Active toys in the home	~	~	~	**4.7 (0.7, 8.6)***
Season				
Summer (Ref)				
Spring	~	~	~	**-16.3 (-32.5, -0.2)***
Autumn	~	~	~	**-29.1 (-59.3, -1.2)***
Winter	~	~	~	**-50.9 (-70.6, -31.2)***
Increment increase in R^2	0.027	0.014	0.059	**0.036***
Total R^2	0.027	0.041	0.100	**0.136***

Notes:
*** p≤0.05**
β represent the difference in MVPA per 1 unit increase in continuous variables or relative difference to reference group in categorical variables. 95% CI = confidence intervals.

Univariate linear regressions (Appendix 6) for WB children (n=333) found 10 variables to be statistically significant (p<0.2). The 9 variables along with sex and BMI z-score were included in multiple linear regressions (Table 6.7). Of the 12 variables four were biological and demographic variables, five social and cultural variables and three environmental variables.

The hierarchical regression models for WB are reported in Table 6.7. Model A (biological and demographic variables) accounted for 1% of the variance which was not statistically significant [$F(9,323) = 0.48$, p≥0.05]. No individual variables were found to be statistically significant.

In step two (model B) social and cultural variables inputted added a further 12.1% to the explained variance, which was statistically significant [$F(29,302) = 1.60$, p≤0.05]. Individual variables that were found to be significant were; 'how often mother or partner encouraged play activities in the last month' [everyday(reference) versus 5-6 times a week (-) and once a week (-)]; 'limiting time watching TV/DVD in the last month' [everyday(reference) versus 5-6 times a week (+) and once a week (+)].

In step three (Model C-final model) environmental variables added a further 5.2% of explained variance which lead to the model significantly accounting for 18.4% of variance [$F(36,297) = 1.65$, $p \leq 0.01$]. Significant individual variables were; 'how often mother or partner encouraged play activities in the last month' [everyday(reference) versus 5-6 times a week (-)]; 'limiting time watching TV/DVD in the last month' [everyday(reference) versus 5-6 times a week (+) and once a week (+)]; 'amount of time child spends in preschool/nursery' [do not attend(reference versus part time (-); and season [summer(reference) versus spring (-), autumn (-) and winter (-)].

Table 6.7: Hierarchical multivariable associations of potential correlates with White British children's MVPA.

POTENTIAL CORRELATES	White British: daily MVPA (n=333)		
	Model A β (95% CI)	Model B β (95% CI)	Model C β (95% CI)
BIOLOGICAL AND DEMOGRAPHICAL VARIABLES			
Sex			
Boys (Ref)			
Girls	-6.0 (-25.4, 13.4)	-7.2 (-27.1, 12.6)	-10.5 (-30.1, 9.1)
Age (months)	-2.5 (-13.0, 8.0)	-2.9 (-14.0, 8.2)	-7.2 (-18.6, 4.1)
BMIz Score	-2.0 (-63,7, 23.2)	-2.6 (-15.9, 10.7)	-3.7 (-17.3, 9.9)
Mothers education			
Higher than A-level (Ref)			
A-level	-30.8 (-72.5, 10.8)	-19.1 (-63.1, 25.0)	-17.8 (-61.0, 25.4)
5 GCSE	-8.6 (-34.7, 17.4)	0.2 (-27.1, 27.6)	-0.3 (-27.4, 26.8)
<5 GCSE	-7.4 (-36.3, 21.5)	-4.9 (-34.1, 24.4)	-4.9 (-33.9, 24.1)
Other	-17.8 (-48.2, 12.5)	-10.2 (-41.4, 21.1)	-8.3 (-39.3, 22.7)
SOCIAL AND CULTURAL VARIABLES			
Mothers number of activity sessions		-1.8 (-4.5, 1.0)	-1.7 (-4.4, 1.0)
How often has mother or partner encouraged child to play active games in the last month			
Every day (Ref)	~		
5-6 times a week	~	**-68.0 (-111.5, -24.6)***	**-55.0 (-98.5, 11.5)***
2-4 times a week	~	4.4 (-21.4, 30.2)	6.0 (-19.4, 31.3)
once a week	~	**-45.9 (-89.7, -2.1)***	-38.2 (-81.7, 5.3)
1-3 times this month	~	-17.1 (-148.2, 114.0)	14.7 (-115.1, 144.5)
Never	~	3.8 (-28.7, 36.2)	9.3 (-23.0, 41.5)
How often mother or partner taken child to places to be physically active in the last month			
Every day (Ref)	~		
5-6 times a week	~	28.9 (-26.7, 84.6)	18.7 (-36.1, 73.6)
2-4 times a week	~	-0.9 (-41.5, 39.7)	-5.1 (-45.9, 35.6)
once a week	~	16.8 (-25.4, 59.0)	9.6 (-33.3, 52.5)
1-3 times this month	~	-15.0 (-60.4, 30.4)	-21.4 (-67.9, 25.1)
Never	~	-7.1 (-59.4, 45.3)	-11.4 (-65.1, 42.3)
Limited time watching TV/DVDs in the last month			
Every day (Ref)	~		
5-6 times a week	~	**61.2 (5.2, 117.3)***	**70.6 (14.8, 126.4)***
2-4 times a week	~	29.5 (-2.9, 61.9)	29.1 (-3.0, 61.2)
once a week	~	**45.1 (9.3, 80.9)***	**50.2 (14.9, 85.4)***
1-3 times this month	~	-12.0 (-65.0, 40.9)	-5.4 (-57.8, 47.0)
Never	~	10.7 (-16.2, 37.5)	14.3 (-12.3, 40.8)
Barrier for child to be active: mother can not take on her own			
Never (Ref)	~		
1-3 times this month	~	13.5 (-26.0, 52.9)	8.8 (-31.4, 49.1)
once a week	~	26.3 (-32.2, 84.9)	29.0 (-29.8, 87.9)
2-4 times a week	~	-16.0 (-69.8, 37.7)	-13.0 (-67.8, 41.7)
5-6 times a week	~	88.3 (-1.0, 177.6)	79.2 (-10.3, 168.7)
Everyday	~	-1.4 (-48.7, 45.8)	3.9 (-44.1, 52.0)
ENVIRONMENTAL VARIABLES			
Amount of time spent at nursery/preschool each week			
Do not attend (Ref)	~	~	
Part time	~	~	**-40.6 (-67.9, -13.2)***
Full time	~	~	6.6 (-31.9, 45.2)
No Active toys in the home	~	~	1.5 (-4.5, 7.5)
Season			
Summer (Ref)	~	~	
Spring	~	~	**-3.6 (-27.3, 20.2)**
Autumn	~	~	**-54.9 (-101.4, -8.5)***
Winter	~	~	**-31.5 (-61.6, -1.5)***
Increment increase in R^2	0.010	**0.121***	**0.052***
Total R^2	0.010	**0.131***	**0.184***

Notes: * p≤0.05; β represent the difference in MVPA per 1 unit increase in continuous variables or relative difference to reference group in categorical variables.; 95% CI = confidence intervals.

Univariate linear regressions for SA children (n=470) (Appendix 6) found 15 variables to be statistically significant ($p<0.2$). The 15 variables along with sex and BMI z-score were included in hierarchical multiple linear regressions (Table 6.8). Of the 17 variables four were biological and demographical variables, three behavioural variables, nine social and cultural variables and one environmental variable.

In the hierarchical regression models (Table 6.8), Model A (biological and demographic variables) accounted for 2.3% of the variance which was not statistically significant [$F(10,460) = 1.20$, $p \geq 0.05$]. Model B (behavioural variables) added a further 4.2% of explained variance, which was not significant [$F(25,445) = 1.28$, $p \geq 0.05$]. There were no significant individual variables in either Model A or B.

In step three (model C) social and cultural variables added a further 8.1% to the explained variance, which was not statistically significant [$F(53,416) = 1.28$, $p \geq 0.05$]. Individual variables that were found to be significant were; 'perceptions of child being as active as peers' [similarly active(reference) versus generally more active (+)]; 'limited time watching TV/DVD's in the last month' [Everyday(reference) versus '5-6 times a week' (+)] and 'barrier for child to be active: the weather' [never(reference) versus 'once a week' (-)].

In step four (Model D-final model) environmental variables added a further 2.8% of explained variance which lead to the model significantly accounting for 17.4% of variance [$F(56,413) = 1.54$, $p \leq 0.01$]. Significant individual variables were perceptions of child being as active as peers' [similarly active(reference) versus generally more active (+)]; 'barrier for child to be active: the weather' [never(reference) versus 'once a week' (-)] and season [summer(reference) versus spring (-) and winter (-)].

Table 6.8: Hierarchical multivariable associations of potential correlates with South Asian children's MVPA.

	SA daily MVPA (n=470)			
	Model A	**Model B**	**Model C**	**Model D**
POTENTIAL CORRELATES	*β* (95% CI)	*β* (95% CI)	*β* (95% CI)	*β* (95% CI)
BIOLOGICAL AND DEMOGRAPHICAL VARIABLES				
Sex				
Boys (Ref)				
Girls	-9.1 (-26.1, 7.8)	-9.5 (-26.9, 7.8)	-4.7 (-22.6, 13.3)	-6.6 (-24.3, 11.0)
Age (months)	5.9 (-3.1, 14.9)	7.2 (-1.9, 16.4)	5.7 (-3.8, 15.3)	1.8 (-8.0, 11.6)
BMIz Score	-0.4 (-11.4, 10.6)	3.8 (-8.8, 16.3)	4.7 (-8.9, 18.3)	4.6 (-8.7, 18.2)
Mothers education				
Higher than A-level (Ref)				
A-level	-19.1 (-52.2, 13.9)	-20.2 (-53.8, 13.4)	-13.1 (-48.4, 22.2)	-13.2 (-48.1, 21.7)
5 GCSE	-10.2 (-33.4, 13.1)	-9.5 (-33.1, 14.1)	-9.1 (-34.2, 16.1)	-10.4 (-35.2, 14.4)
<5 GCSE	-12.0 (-35.7, 11.7)	-10.5 (-34.7, 13.7)	-4.4 (-30.1, 21.2)	-4.7 (-30.0, 20.6)
Other	-33.0 (-68.5, 2.6)	-29.7 (-66.2, 6.8)	-25.2 (-63.7, 13.2)	-21.2 (-59.2, 17.0)
Mother ever smoked				
No (ref)				
Yes	17.8 (-6.5, 42.2)	-19.2 (-44.0, 5.7)	-25.7 (-51.6, 0.2)	24.5 (-0.9, 49.8)
BEHAVIOURAL VARIABLES				
How often child watched TV at meal times				
Never (Ref)				
1-3 times this month	~	-22.8 (-57.8, 12.2)	-9.6 (-45.9, 26.6)	-11.9 (-47.6, 23.8)
once a week	~	-28.9 (-63.3, 5.4)	-23.3 (-58.9, 12.2)	-25.8 (-61.0, 9.3)
2-4 times a week	~	-1.5 (-28.2, 25.3)	-2.4 (-30.6, 25.8)	-2.6 (-30.4, 25.1)
5-6 times a week	~	13.8 (-26.4, 54.1)	7.8 (-35.0, 50.6)	0.3 (-42.2, 42.8)
Everyday	~	5.1 (-18.9, 29.0)	1.8 (-23.5, 27.1)	-0.1 (-24.9, 24.9)
TV Screen Time before 6pm on Weekend days				
None (Ref)				
<1 hour	~	7.5 (-18.6, 33.5)	4.1 (-22.9, 31.0)	2.1 (-24.6, 28.8)
1-2 hours	~	6.1 (-21.9, 34.1)	7.6 (-21.1, 36.4)	4.4 (-24.0, 32.8)
2-3 hours	~	-25.9 (-59.6, 7.9)	-25.5 (-60.8, 9.8)	-24.3 (-59.2, 10.7)
3-4 hours	~	-33.3 (-76.3, 9.8)	-34.5 (-78.5, 9.6)	-34.7 (-78.0, 8.6)
>4 hours	~	-37.1 (-96.1,21.9)	-26.2 (-86.6, 34.2)	-24.2 (-84.3, 35.8)
TV Screen Time after 6pm on Weekend days				
None (Ref)				
<1 hour	~	-16.5 (-36.6, 3.7)	-15.5 (-36.4, 5.3)	-15.1 (-35.8, 5.5)
1-2 hours	~	-9.3 (-35.9, 17.3)	-8.3 (-36.4, 19.8)	-8.8 (-36.5, 18.9)
2-3 hours	~	27.4 (-32.2, 86.9)	26.9 (-34.3, 88.1)	24.6 (-35.6, 84.7)
3-4 hours	~	-17.7 (-154.6, 119.1)	-57.4 (-199.1,84.5)	-69.8 (-209.4, 69.8)
>4 hours	~	84.6 (-96.1, 21.9)	75.0 (-41.1, 191.2)	80.4 (-34.2, 195.1)
SOCIAL AND CULTURAL VARIABLES				
Childs weight compared to others				
About the same (Ref)				
much thinner	~	~	-8.9 (-63.9, 46.1)	-0.2 (-54.4, 54.0)
a little bit thinner	~	~	6.4 (-14.9, 27.7)	6.8 (-14.2, 27.7)
a bit heavier	~	~	6.3 (-19.0, 31.7)	7.8 (-17.3, 32.8)
Mothers weekly MPA minutes	~	~	-0.2 (-0.4, 0.1)	-0.2 (-0.4, 0.3)
Mothers weekly VPA minutes	~	~	-0.04 (-0.2, 0.2)	0.1 (-0.2, 0.2)
Perceptions of child being as active as peers				
Similarly active (Ref)				
generally more active	~	~	**21.4 (2.7, 40.2)***	**18.9 (0.2, 37.6)***
generally less active	~	~	12.1 (-42.3, 66.5)	4.7 (-49.0, 58.4)
Important child does not watch too much TV				
Agree (Ref)				
neither agree or disagree	~	~	10.5 (-26.3, 47.2)	13.4 (-22.8, 49.6)
disagree	~	~	-15.7 (-42.5, 11.2)	-13.5 (-39.8, 12.8)
How often has mother or partner played an actively with child in the last month				
Every day (Ref)				
5-6 times a week	~	~	0.4 (-32.8, 33.5)	5.9 (-26.9, 38.7)

2-4 times a week	~	~	12.9 (-10.3, 36.1)	17.9 (-5.0, 40.9)
once a week	~	~	-24.2 (-57.3, 8.9)	-15.0 (-47.6, 17.5)
1-3 times this month	~	~	-17.7 (-69.9, 34.5)	-16.4 (-68.0, 35.3)
Never	~	~	19.7 (-17.7, 57.1)	21.1 (-15.4, 57.5)
Limited time watching TV/DVDs in the last month				
Every day (Ref)				
5-6 times a week	~	~	**42.1 (0.5, 83.8)***	33.4 (-7.8, 74.7)
2-4 times a week	~	~	30.2 (-1.6, 62.1)	26.7 (-4.7, 58.2)
once a week	~	~	7.0 (-36.9, 51.0)	-0.1 (-43.7, 43.4)
1-3 times this month	~	~	31.1 (-27.2, 89.4)	25.4 (-32.1, 82.9)
Never	~	~	17.3 (-5.4, 39.9)	7.5 (-14.7, 29.7)
Barrier for child to be active: weather				
Never (Ref)				
1-3 times this month	~	~	-10.1 (-38.5, 18.3)	-3.9 (-32.0, 24.1)
once a week	~	~	**-39.2 (-69.1, -9.4)***	**-34.3 (-63.9, -4.7)***
2-4 times a week	~	~	4.4 (-20.1, 29.0)	3.3 (-20.2, 26.8)
5-6 times a week	~	~	-27.7 (-76.6, 21.2)	-16.4 (-64.9, 32.1)
Everyday	~	~	-24.0 (-61.9, 14.0)	-10.0 (-47.9, 27.8)
Parenting: feeling depressed				
None of the time (Ref)				
A little of the time	~	~	2.2 (-20.0, 24.4)	4.6 (-17.3, 26.5)
Some of the time	~	~	25.2 (-2.4, 52.9)	26.7 (-0.5, 53.9)
Most of the time	~	~	-3.4 (-53.1, 46.3)	1.2 (-47.9, 50.3)
All of the time	~	~	-33.6 (-120.5, 53.2)	-23.7 (-109.2, 62.1)
ENVIRONMENTAL VARIABLES				
Season				
Summer (Ref)				
Spring	~	~	~	**-23.5 (-46.1, -0.9)***
Autumn	~	~	~	3.3 (-40.7, 47.3)
Winter	~	~	~	**-52.1 (-79.6, -24.7)***
Increment increase in R^2	0.023	0.042	0.081	**0.028***
Total R^2	0.023	0.065	0.146	**0.174***

Notes:
* p≤0.05
β represent the difference in MVPA per 1 unit increase in continuous variables or relative difference to reference group in categorical variables.; 95% CI = confidence intervals.

6.5. Discussion

This study is the first known to investigate habitual MVPA and correlates of MVPA in a bi-ethnic sample of toddlers (2-4 years). Findings of this cross-sectional study indicate that toddlers living in the city of Bradford reportedly took part in high levels of daily MVPA, and ethnic differences in habitual MVPA seen between WB and SA children[87-90] may not begin in toddlerhood. However, the context of where MVPA was undertaken did differ between ethnicities and although few correlates of MVPA were identified, different correlates were found for SA and WB children.

6.5.1. Levels of moderate-to-vigorous physical activity

The current study found Bradford toddlers spent a reported 18% of their waking day in MVPA. The 18% equates to 157 minutes of MVPA daily, which is near to three hours (180 minutes). This level of daily MVPA is extremely high when considering previous research has found that activity of young children increases year by year until the age of five.[111,118] At age five a drop of activity begins and occurs then throughout childhood[118,419], meaning for the current study such high levels of MVPA during toddlerhood would suggest this cohort of children will be extremely active once five years of age. Such a reported high level of MVPA could be because of the subjective nature of the EY-PAQ, and even after considering potential outliers parents could well be biased in reporting children as more active than they are, or are reporting LPA as MVPA, and therefore an inflated value has been reported. When considering findings from energy expenditure studies,[12,420] the idea that the current results are inflated and unrealistic are strengthened, as such energy expenditure studies (gold standard measurement) report young children have low levels of daily energy expenditure and the ability to undergo nearly three hours of MVPA appears to be unrealistic. However, when transforming the value of 157 minutes into a proportion (18%) and comparing to other studies of the thesis, 18%

is lower than both accelerometry (20.3%) and EY-PAQ (21.2%) proportions reported in Chapter 5, and higher than MVPA proportions reported in Chapter 4 (mean: 9.8% and median: 11.2%). But, having high confidence in the actual levels of MVPA accumulated by toddlers is difficult across the literature due to differences in measurement techniques adopted across studies. A systematic review investigating the objective levels of young children's PA levels, by Hnatiuk[111], identified 37 unique samples from 40 studies. The main findings were young children spent between 2% and 41% of their waking hours in MVPA, which translates to a range of 15 minutes to 320 minutes of daily MVPA, when standardised across expected waking hours for this age group. It should be noted that as the EY-PAQ boundaries implemented (Chapter 5) to exclude extreme values were 2% to 41%, proportional levels reported in the present study were never going to be higher than 41% (320 minutes-based on a 840 minute waking day). The majority of studies in the Hnatiuk[111] review reported preschool children's levels of PA. Only three studies are known to report toddler's levels of MVPA.[281,376,407] Gubbels[281] using direct observation, found toddlers (n=75 two year olds) engaged in MVPA for 5% of the time spent indoors at a childcare centre and 21% of the time when outdoors. Wijtzes[376] and Hnatiuk[407] like the current study measured habitual levels of MVPA. Wijtzes[376] assessed 2 year old Dutch children's physical activity via accelerometry and found children spent 5% of their daily waking time in MVPA. Hnatiuk[407] assessed 19 month old Australian children's levels of activity and found 8.2% of waking hours (mean) were spent in MVPA, with a range of 2.6% to 18.5%. Measurement of MVPA and PA is difficult to gage particularly when different studies use different measurements (direct observation, accelerometry, heart rate monitoring)[111] and studies using accelerometry use different data reduction choices (e.g. wear-time, non-wear-time, cut-points; see sections 1.2.2.6.5. and 1.2.2.6.6.). It is also important to note that proxy report questionnaires, as used herein, are likely to be confounded by social desirability bias and recall error.[196] Nevertheless, as there are no comparable studies (using the EY-PAQ) reporting levels of toddlers habitual

MVPA, and both Hnatiuk[407] reported proportions of MVPA to be lower than 10%; in the current study Bradford toddlers were found to be highly active, especially when converting 18% of MVPA in to minutes (157.6 minutes), which is nearly three times the recommended 60 minutes of daily MVPA for older children.

6.5.2. Levels of moderate-to-vigorous physical activity – differences between ethnicities

Bradford toddlers being found to be highly active is a good public health finding. However, such positive news does not mean promotion of PA particularly MVPA should become less of a public health priority. Physical activity levels reduce as age increases[121] and also track from the preschool years into the primary pre-puberty years.[118] Therefore, maintaining and maximising levels of MVPA is important, particularly for communities like Bradford which have a high number of people of SA ethnicity who have been reported to take part in significantly less PA and MVPA than their WB peers in older childhood,[87-89] which could contribute to a potential public health crisis due to SA's having a higher predisposition for chronic diseases which high levels of PA can help prevent (type II diabetes mellitus, cardio-vascular disease and obesity).[91-100]

The current study found no significant differences between habitual levels of MVPA between WB and SA children. This is in line with the findings of the systematic review in Chapter 3[72]; which reported no difference of MVPA levels between young children of different ethnicities. However, studies identified were with mainly American populations and compared differences between Hispanic, Black and White American preschool populations. This is the first study to examine ethnic difference between WB and SA British populations during toddlerhood. Although no differences were found between ethnicity and habitual MVPA, previous research in older children has consistently found WB children to have significantly greater levels of PA compared to their SA peers.[87-90] Therefore, future research of a longitudinal design should seek to investigate when differences between WB and SA children occur and understand the factors associated with any differences.

The current study used the EY-PAQ, a proxy-report questionnaire found to have acceptable validity and reliability in Bradford young children (See Chapter 5[406]), as the measure of MVPA. A strength of the EY-PAQ is the contextual information which describes the different activities, which summed together, calculate overall MVPA. After taking into account season, sex, BMIz and age, SA children spent significantly more time taking part in activity inside the home than WB children, and WB children spent significantly more time being active while walking for transportation. Although clear limitations surrounding proxy report questionnaires should always be considered, this is an important finding as it indicates what constitutes MVPA may well be different for WB and SA young children, and future research targeting specific contexts of MVPA for different ethnicities may yield greater success in increasing overall MVPA.

6.5.3. Correlates of moderate-to-vigorous physical activity

The present study examined a wide range of potential correlates covering the different levels of the ecological model. For the sample as a whole the found correlates were mother's education, limited time watching TV/DVD's in the last month, barrier for child to be active: the weather, number of active toys in the home and season. When the sample was stratified by ethnicity correlates varied between WB and SA children. For WB children correlates found were how often mother or partner encouraged play activities in the last month, limiting time watching TV/DVD in the last month, the amount of time the child spends in preschool/nursery and season. For SA children correlates found were child being as active as peers, barrier for child to be active: the weather and season. As correlates of PA differed for different ethnicities future studies may need to recruit sufficiently large samples to ensure adequate power to stratify analyses by ethnicity, especially in communities like Bradford where the population is predominately made up of two ethnic groups. Future research should explore this issue more closely and aim to understand the possible cultural differences of PA between ethnic groups. This is so future interventions can apply suitable strategies to increase the likelihood of successful outcomes.

There were a number of interesting individual findings. Firstly it was reported in chapter 3 (systematic review) that child's sex is a correlate of TPA and MVPA. In the current study boys were found to be significantly more active than girls for the whole group and for SA children, but only in univariate analyses. The association ceased to be significant in any of the hierarchical multiple regression models. Wijtzes[376] and Foweather[421]both examined differences in MVPA between toddler boys and girls. Wijtzes[376] found boys to be significantly more active and Foweather[421] did not. However, Foweather[421] like the current study did not observe significant differences between boys and girls MVPA, but the direction of associations were trending towards boys being significantly more active than girls. In light of sex being the only consistently reported correlate and determinant of children's PA in previous published research[134], and correlates of PA differ for preschool children by sex,[283] future research should be aware of this, even though the current study did not find any differences between sexes. Future studies should seek to identify sex-specific strategies to be implemented in future interventions. Although sex differences for SA children in the current study were only found to be significant in univariate models, future research should investigate the sex differences of young SA children using a more objective accurate measure of MVPA.

A consistent correlate of MVPA for the whole sample and for both SA and WB toddlers was season, with significantly less MVPA being reported for toddlers whose mothers completed the questionnaire in the winter months (December, January and February) compared to mothers completing the questionnaire in the summer months (June, July and August). Carson[64] reported in a review that seasonal differences (winter PA being less than summer) were consistently found regardless of the region, measure of PA, or the study design. However, as the present study was cross-sectional and compared MVPA between toddlers measured in each season, future longitudinal research should be undertaken in this age group to further examine these findings, and also seek ways to increase PA during the winter months.

A novel finding of this study was that parents who limited their child's TV/DVD viewing to fewer times in a week reported higher levels of MVPA for their child, compared to parents who limited TV/DVD use on a daily basis. This finding does not appear to be logical, however no known study has found a similar association with restricting TV/DVD use being associated with greater PA. However, as the EY-PAQ is a proxy reported questionnaire, social desirability bias could be a confounding issue explaining this association. With TV and screens being a common fixture in modern homes more research is needed to understand the relationship between toddlers MVPA and screen viewing, particularly regarding parental rules around screen viewing.

6.5.4. Limitations

This study like all studies had a number of limitations. Firstly, because of the cross-sectional design, causality cannot be assigned to any finding. Secondly, this study was a secondary analysis of data being collected as part of birth cohort study, because of this a large range of variables hypothesized to be associated with health were measured, which were not based upon any particular theory or model. Such approach increases the risk of researchers 'data dredging/P-hacking'. To overcome such a risk the approach of the current study's analysis was to include as many possible variables from the full data set only excluding variables with missing data, then pursing with the analysis which was conducted. The data analysis was also designed and pre-registered with the Born in Bradford executive committee (http://www.borninbradford.nhs.uk/research-scientific/how-to-request-access-to-raw-bib-data/). A third limitation was that many variables measured as part of the BiB1000 study were selected out of convenience and for exploratory reasons, and not based upon whether particular questions/measures had good reliability or validity, therefore this should be considered when interpreting the results. A fourth limitation, was the subjectivity of many the variables being measured. Like the outcome measure most of the potential correlates were measured via proxy report (answered by mothers), as required when assessing children of such a young age. Therefore, social desirability bias, poor recall and in the case of the EY-PAQ, subjective determination of activity could have led to high inaccuracy across the outcome measure and independent variables.[196] A fifth limitation was the current study like previous correlates research has assigned a binary yes/no correlate category to exposure variables, meaning no further explanation or further understanding of the level of association of exposure variables is reported/known. The choice of continuing with this type of analysis was because this was the first known study to explore correlates separately for different ethnicities of toddlers; and with the large amount of explorative exposure variables following a similar analysis to previous correlates research would help fill the ethnicity correlate gap reported in Chapter 3. Future research should aim to conduct an analysis with fewer exposure variables, along with testing the level of explained variance for each of the exposure variables. Such analysis would better inform future interventions.

6.5.5. Strengths

Despite the limitations this study has a number of strengths. Firstly, this study has the largest sample size of any known study measuring PA in toddlers, specifically

MVPA. Although the use of a proxy report questionnaire to measure MVPA is a limitation and increases the risk of inflated estimates of MVPA, the EY-PAQ has been found to have acceptable validity and reliability in the Bradford population and also in both Urdu and English languages, meaning without the use of the EY-PAQ such a large sample would not have been feasible and Urdu speakers could well have been excluded if another questionnaire was used. Another strength of the use of the EY-PAQ is the extra contextual information gained. Habitual MVPA was measured by the EY-PAQ but so were the components which make up MVPA. Because of the large sample size of a population with large proportion of SA inhabitants the current study had the power to be able to stratify the sample by ethnic group and examine the correlates of MVPA for each ethnic group individually – providing information which could be used in the planning of and designing of future interventions.

6.6. Conclusions

This study found Bradford toddlers to be highly active, with no difference between WB and SA toddlers levels of habitual MVPA. However, SA children spent more of their MVPA time in the home compared to WB children, and WB children spent significantly more of their MVPA time walking for transportation. A small number of correlates of MVPA were identified, with different correlates found separately for WB and SA toddlers; meaning to maintain and maximise high levels of toddlers MVPA, future interventions should seek to tailor interventions by ethnicity.

Findings of this study help to increase the understanding of MVPA levels of 2 year old children living in a predominately bi-ethnic low socio-economic class city; and can help inform the development of future interventions aiming to maintain and/or increase high levels of young children's MVPA.

CHAPTER 7 – Conclusions

7.1. Key Findings and Implications

The studies in this thesis were standalone studies but with a thread linking the studies together. Outlined in Chapter 2 is the flow and interconnection of the different chapters of the thesis (see figure 2.2). As the studies in Chapters 3 to 6 had individual discussion, limitations and conclusion sections, this chapter will reiterate and summarise key findings, and then present the implications of the studies within the thesis and report directions for future research.

7.1.1. Chapter 3

The aims of the systematic review in this chapter was to synthesize studies investigating potential correlates and determinants of TPA, MVPA, and LPA in children during the early years and investigate potential differences in associations by measurement method. A large number of studies were identified in this deliberately broad reaching review. The key findings of the review were few studies were graded as high quality (based upon the STROBE guidelines[249,251]), and all studies took place in high income countries. Identified correlates of TPA were sex (boys more active than girls), parental PA and time outdoors. The only identified correlate for MVPA was sex, and no correlate was identified for LPA. Determinants of TPA were again sex (boys more active than girls) and time spent playing with parents. No determinants of MVPA or LPA were found. PA correlates/ determinants were relatively consistent between objective and subjective PA measures, however only one study used both objective and subjective measures in the same sample.

Although a large number of studies investigated potential correlates and determinants of PA, few correlates and determinants (modifiable and non-modifiable) were identified and overall quality of studies was deemed low. A small number of demographic/biological and social/cultural factors were associated with the different intensities of PA. Of the many findings of the review the remainder of the chapters within this thesis concentrated on the findings of little research investigating and examining the differences in correlates between ethnic groups of WB and SA children, and the observation of only a small number of studies examining potential correlates in toddlers of MVPA.

7.1.2. Chapter 4

The study in this chapter was undertaken in order to clarify an accelerometer wear-time criteria in order to undertake a validation study of the Early Years Physical Activity Questionnaire (EY-PAQ), a proxy reported questionnaire which estimates young children's habitual MVPA and ST. The aims of this study were to firstly identify the wear-time criteria to reliably estimate habitual PA and ST levels of young children living in Bradford; and secondly present the methods used as a worked example in a simple stepped-process to aid researchers when deciding on the number and type of days (weekday and/or weekend) of accelerometer data required to reliably estimate the habitual PA and ST of a sample of young children. Findings of the study identified that reactivity did not occur, there were no differences between weekdays and weekend days, leading to a minimum of six hours of data on any three days as sufficient to reliably estimate young children's habitual PA who live in the city of Bradford.

7.1.3. Chapter 5

The aims of this study were to assess the EY-PAQ's test re-test reliability, and to determine its validity by comparing EY-PAQ data to accelerometry in a sample of young children from the city of Bradford, a deprived and multi-ethnic population; where English and Urdu are the predominant languages spoken. Within the accelerometry data the processing rules for the wear-time criteria presented in chapter 4 were applied in this study.

The EY-PAQ was found to have unacceptable validity for ST, but had acceptable test re-test reliability and validity for measuring habitual MVPA of young children from a bi-lingual (English, Urdu), bi-ethnic (White British, South Asian) low socio-economic community. However, MVPA validity was only deemed acceptable after converting EY-PAQ values in to proportions (based upon a waking day) and excluding proportions outside of the boundary values 2% to 41%. The proportion values 2%-41% were based upon previous studies using objective measures.[111]

In situations when objective methods such as accelerometry are not possible for measurement of MVPA in young children, the EY-PAQ could be a suitable alternative, but only if the processing methods of data outlined in the study are followed and applied. Although the EY-PAQ was deemed suitable in English and Urdu in the study's sample, the sample came from a unique population, therefore the findings of this study are not generalizable to other samples from different populations.

7.1.4. Chapter 6

Because the EY-PAQ was found to have acceptable reliability and validity in a sample of Bradford 2-3 year olds, it meant the use of the BiB1000 cohort data could be utilised to undertake a large correlates study of Bradford toddlers. The aim of the study in chapter 6 was to increase understanding of levels of MVPA and correlates of MVPA in a large sample of WB and SA toddlers from Bradford.

Findings of the study indicated that Bradford toddlers were highly active, and no ethnic differences in habitual levels of MVPA were observed. However, ethnic differences were found between the domains of MVPA. South Asian children spent more of their MVPA time in the home compared to WB children, and WB children spent significantly more of their MVPA time walking for transportation.

For the whole sample (n=837) individual observed correlates were mothers education, limited time watching TV/DVD's in the last month, the weather, number of active toys in the home and season. For WB children individual observed correlates were how often mother or partner encouraged play activities in the last month, limiting time watching TV/DVD in the last month, the amount of time child spends in preschool/nursery and season. For SA children individual correlates were mother seeing child being as active as peers, the weather and season. The only multivariable regression models (whole sample, WB and SA) to be statistically significant were the final hierarchical models which included multiple layers of the ecological model.

The findings of the current study could aid the development and design of future interventions seeking to maintain and maximise the high levels of MVPA of Bradford toddlers found in the current study.

7.2. Future Research

The studies of this thesis have pragmatically investigated topics within two stages of the behavioural epidemiological framework for young children's PA – measurement and correlates/determinants. The systematic review presented in chapter 3 identified a large number of studies and thus recommended a large number of areas for future research to investigate. Many recommendations were made for future research in this chapter and can be found in the discussion and conclusion sections of chapter 3. The most important findings of the systematic review was the small number of correlates and determinants found across the literature for TPA, MVPA and LPA, particularly few modifiable correlates. This finding was surprising for correlates as a large number of studies examined the cross-sectional differences between independent variables/potential correlates and measures of PA. As for found determinants it was not surprising few were identified because only a small number of longitudinal studies had taken place. The reason for a small number of correlates could be because of the lack of high quality studies across the literature. However, many studies may have been of higher quality then what was graded by the two reviewers but instead the reporting of results was poor. This issue of poor reporting has also been identified by a leading journal (International Society of Behavioral Nutrition and Physical Activity) of PA epidemiology[422], and the journal has recommended following the STROBE guidelines for cross-sectional studies for any future papers submitted to the journal.[251] Future cross-sectional and correlates research should aim to follow this recommendation.

Another key finding of the systematic review in Chapter 3, was there was no found difference between correlates of studies using objective measures (accelerometers, heart rate monitors, pedometers etc.) and subjective measures (proxy-report questionnaires). This is an interesting finding which could be viewed from two perspectives. The first perspective is both types of measures confirming a no and/or a positive/negative association of a correlate and determinant, increases the confidence in the found association. The second perspective is the value of subjective measures is strengthened in identifying direction of associations, because the same association has been found by studies using more accurate objective measures. However, although objective measures such as accelerometers are conceptually superior at measuring PA compared to the subjectivity of questionnaires, especially proxy-reported questionnaires, objective measures are still hindered by numerous issues. An example is accelerometry and the subjective choices researchers need to make when using accelerometers to measure PA including, monitor placement, intensity cut-points, non-wear time, epoch length and wear-time. For the first perspective it must be noted only one study used both objective and subjective measures. Future research should aim to use both types of measures in the same sample, even if objective measurement is collected for a sub-sample within a large sample study which uses subjective measurement (questionnaires) as the main outcome measure. For the second perspective future research should aim to refine the limitations of objective measures to increase confidence and validity and reliability.

Chapter 4 aimed to investigate one of the subjective choices researchers make while processing accelerometer data – wear-time criteria. The decision of accelerometer wear-time criteria is still an unclear issue for the early years PA literature (see section 1.2.2.6.6.). The study in Chapter 4 found there was no reactivity, no differences between weekend days and weekend days and a minimum of six hours on any three days was enough to reliably estimate the TPA, CPM, LPA, MPA, MVPA and ST of young Bradford children. Issues such as reactivity, weekday difference and number of days required to reliably estimate PA should be a priority for researchers to justify in future studies. Not one of the methods applied in the previous wear-time reliability studies[203,204,382] were statistically incorrect or weaker from one another; however methods were/are difficult to follow, this is why a simple stepped process was presented in this chapter. The findings across the studies show the nature of PA is different between populations and different countries, which means a universal wear-time criteria does not appear to be obtainable. Therefore, researchers in the future could use the simple stepped process presented in chapter 4 in future studies to get the most out of their own accelerometer data and calculate a specific wear-time criteria for individual samples, this will lead to higher quality studies which are less likely to under or overestimate PA .

The study in chapter 5 found the EY-PAQ to have acceptable test re-test reliability and validity in estimating young children's average daily MVPA over a seven day period, compared to accelerometry. Future research should seek to test the validity of the EY-PAQ with parents and young children from different communities. This is because of the uniqueness of the Bradford population compared to the rest of the United Kingdom. Moving away from the PA interest of this thesis, the EY-PAQ was not found to be valid in estimating young children's habitual ST. Future research could seek to amend the questions and domains of the EY-PAQ which measure ST.

In chapter 6 it was found toddlers (two years of age) were highly active and there was no difference between WB and SA children's levels of MVPA; however, from previous research in older children a greater proportion of the wider UK population become more inactive, and WB children are more active than SA children (8-9[423] and 11-14[87] years of age). Future longitudinal research is required to establish the age and developmental stage when activity declines, and when a difference between WB and SA children's PA (MVPA and TPA) first occurs.

Although the results of Chapter 6 offer promise in that Bradford toddlers were highly active, future research should still aim to measure Bradford young children's MVPA levels using both objective and subjective measures. This recommendation not only follows on from the findings in Chapter 3, but also because both the EY-PAQ and accelerometry can provide reliable and valid estimates of habitual MVPA but only accelerometry can provide a measure of whether children are meeting PA guidelines. Future research should also use both types of measurement because subjective measures, like the EY-PAQ, can provide contextual information. This is important, because as the results in Chapter 6 found, habitual MVPA may not have differed between SA and WB Bradford toddlers, but the domains of where and how toddler took part in MVPA did differ. In regards to the specific findings of Chapter 6, future research (correlates, determinants and qualitative [barriers, facilitators]), in the pursuit of developing future interventions, should further examine why SA toddlers spent more of their daily MVPA in the home compared to WB toddlers, and also why WB toddlers spent more time of their MVPA walking for transport compared to SA toddlers. Understanding factors associated with MVPA domains such as MVPA in the home could lead to the refinement of future interventions.

The study in Chapter 6 was the first known study to utilise the ecological model to examine correlates of PA with Bradford children (of any age). It was found multiple-regression models only predicted MVPA significantly better than the mean average as a model, when multiple levels of the ecological model were inputted into regression models. This finding adds support to the ecological perspective upon PA (see section: 1.1.8). However, the measurement quality of many of the potential correlates was unknown and must be taken into consideration when interpreting results. Future research should build upon the results of the study in Chapter 6 by conducting more observational (cross-sectional/prospective) studies using more valid and reliable measures of both the outcome and predictor variables (potential correlates and determinants), and to examine the relationship between different layers of the ecological perspective and build upon the work by Spence[424] to develop a more refined and comprehensive ecological model specific to PA during the early years.

In chapter 6, correlates found for SA and WB toddlers were not as numerous as correlates found for the whole sample. However, the correlates found for WB toddlers were different than correlates found for SA toddlers. Researchers planning and designing protocols for cross-sectional, longitudinal and intervention studies in communities with large ethnic groups such as Bradford, should be mindful of this finding. For cross-sectional and longitudinal research future studies will need to recruit large samples to ensure adequate power to stratify analyses by ethnicity. For future intervention studies, strategies to tailor interventions by ethnicity must be considered. However, what strategies to apply and consider is unknown and future research should seek to investigate this further, first through observational research (quantitative and qualitative research) and then through piloting of strategies.

There were multiple individual correlates of toddler's MVPA found in Chapter 6. Two individual correlates of interest were sex and season. Children's sex is the most widely reported correlate and determinant of pre-pubertal children,[134] and was found to be a correlate of young children's (0-6 years) TPA and MVPA in the systematic review in Chapter 3. In chapter 6, levels of MVPA were not found to be significantly different between boys and girls in any of the multivariable models; but boys were found to be significantly more active than girls in the univariate analysis for the whole sample and SA toddlers. Future research should further investigate the sex differences of toddlers, especially SA children, in light of the large amount of evidence showing boys are more active than girls, and that correlates of TPA differ between preschool boys and girls.[425] Like the recommendations for ethnicity, future interventions should consider applying strategies to tailor interventions by sex, if strategies are unknown further observational and pilot work will also be required. Season was consistently found to be a correlate of toddler's MVPA in Chapter 6, with greater levels of MVPA being reported by mothers in the summer months compared to mother reporting MVPA levels in the winter months. Because of the subjectivity of the EY-PAQ and the cross-sectional nature of the study in Chapter 6, future longitudinal research using an objective measure with Bradford young children is needed to strengthen this seasonal difference hypothesis. If a seasonal difference becomes more evident then future research should further investigate why a seasonal difference occurs and to also prioritise times of the year to implement interventions to maintain or increase MVPA of young children.

7.3. Implications

The findings of the review in Chapter 3 and novel findings in the studies in Chapters 4, 5 and 6 have all contributed and have had/will have significant implications on PA research during the early years.

Chapter 3 offers researchers a vast systematic review which synthesised published research which reported cross-sectional (correlates) and longitudinal (determinants) associations of young children's TPA, MVPA and LPA. The systematic review also synthesised associations according to the type of PA measurement used (objective and subjective). The implication of the systematic review is researchers and policy makers now have an important resource (see: [72] (particularly the appendices [appendix 3]) which can inform future research and public health policies.

There are two implications which come from the wear-time reliability study in Chapter 4. The first is future studies which have a sample of young children from Bradford now have a wear-time criteria which can reliably estimate accelerometer TPA, MVPA, LPA and ST. An example of this implication in action is the wear-time criteria applied in the study in Chapter 5 which has been peer reviewed and published.[406] The second implication, is as the methods of the study were clearly presented in six-steps, researchers can now easily follow these steps to calculate a sample-specific wear-time criteria; thus researchers and readers alike can have greater confidence that the full potential of data is being used and also have greater confidence in the accuracy of accelerometer PA levels.

Objectives methods such as accelerometers are and should be the first choice for the surveillance of PA levels. However, expertise required to process data, financial cost and feasibility means the use of objective measures are only really available to be used by PA researchers. The results in Chapter 5 showing the EY-PAQ has acceptable validity and reliability means an alternative tool which is cheap, easier to distribute and easier to derive and process data, is now available to estimate MVPA levels of young children living in Bradford and other similar bi-ethnic (predominately SA and WB) communities. The implications of the availability (see: Bingham[406]) and strengths of the EY-PAQ means not only researchers but also health practitioners and other institutions interested in young children's MVPA (e.g. preschools, children centres), now have a suitable tool to measure MVPA levels. The EY-PAQ is also a tool which can not only estimate young children's habitual MVPA levels, but can also rank children's habitual MVPA levels and break down MVPA into different domains. The implications of this is the EY-PAQ could be used to determine correlates, determinants and refine MVPA levels into different domains, which all can inform future intervention and policy development. An example of the use of the EY-PAQ in reporting levels and correlates of MVPA was shown in the study in Chapter 6.

Results of Chapter 6 add to the small but growing literature of levels and correlates of toddlers MVPA. The finding that high levels of MVPA in toddlers, informs researchers and policy makers that although toddlers in Bradford may be highly active, future public health priorities should not move away from PA promotion in toddlers. Instead a priority should be that PA levels are maximised and maintained into preschool and school-aged children; especially in light of the first years of life being critical for the growth and development process[78], and also to begin to halt and reverse the rise of non-communicable diseases being found in younger children.[237]

Results of Chapter 6 (different correlates and contexts of MVPA for different ethnicities) adds support to the view modifiable correlates of health behaviours may not be the same for one ethnic group compared to another,[79,80] thus researchers, local authorities and other policy makers should consider developing strategies to tailor interventions in accordance to ethnicity. This issue is of great importance because people of ethnic minorities, particularly of SA ethnicity, have a higher predisposition for chronic diseases (type II diabetes mellitus, cardio-vascular disease and obesity),[91-100] of which markers of onset have been observed in children.[118,119] The addition of early health interventions, such as PA interventions, could aid in the prevention and even reverse disparities in health seen in many ethnic minorities.[82,102-105]

7.4. Conclusion

In conclusion, this PhD thesis ultimately aimed to enhance the understanding of young children's physical activity. Findings from this thesis have provided evidence and greater understanding of this growing research area, particularly regarding ethnicity and measurement. Through a comprehensive correlates and determinants systematic review, and three novel studies (two measurement, one epidemiological) utilizing data from a novel and unique sample (Bradford – a bi-lingual and bi-ethnic population), the key findings were; an increased need for more high-quality studies exploring correlates/determinants across all layers of the ecologic model, and that research investigating MVPA correlates/determinants of toddlers and between ethnicities is sparse. Knowledge of young children's objective physical activity measurement and subjective physical activity measurement is now enhanced through a new accelerometer wear-time calculation and a validated bi-lingual (English and Urdu) parental questionnaire (EY-PAQ)- both acceptable and suitable for future investigation of young children's physical activity. Levels of toddlers' MVPA were found to be unusually high, did not differ by ethnicity but most interestingly the contexts and correlates did. This means future interventions should seek to maintain and maximise levels of toddlers' MVPA and tailor interventions by ethnicity. The research conducted within this thesis will inform the development of surveillance, interventions and public health policies to improve young children's PA levels, particularly children living in a bi-ethnic community.

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Appendices

Appendix 1. – Abstracts of Published **Research**

ARTICLE IN PRESS

Physical Activity During the Early Years

A Systematic Review of Correlates and Determinants

Daniel D. Bingham, MSc,[1,2] Silvia Costa, PhD,[3] Trina Hinkley, PhD,[4] Katy A. Shire, BSc Hons,[5] Stacy A. Clemes, PhD,[1] Sally E. Barber, PhD[2]

Context: Being physically active during the early years (age 0–6 years) is vital for healthy development. Identifying correlates and determinants of physical activity (PA) is crucial to guide effective interventions. This systematic review synthesized studies investigating potential correlates and determinants of PA during the early years, accounting for different types of PA assessment.

Evidence acquisition: Nine electronic databases were searched from inception year (1900) until September 2014; data were analyzed/interpreted in April 2015. The following inclusion criteria were used: written in English, published in peer-reviewed journals, participants not in statutory/school education, and an observational design investigating associations between an exposure/variable, and a quantitative measure of PA. Correlates/determinants of total, moderate to vigorous, and light PA were reported using an ecologic model.

Evidence synthesis: Of 22,045 identified studies, 130 were included. All took place in high-income countries and few (6%) were of high quality. Correlates of total PA were sex (male, ++); parental PA (+); parental support (+); and time outdoors (+). Determinants of total PA were sex (+) and time spent playing with parents (+). The only correlate of moderate to vigorous PA was sex (male, ++). No determinants of moderate to vigorous or light PA were found. PA correlates/determinants were relatively consistent between objective and subjective PA measures.

Conclusions: Numerous studies investigated potential correlates and determinants of PA, but overall quality was low. A small number of demographic/biological and social/cultural factors were associated with PA. There is a need for high-quality studies exploring correlates/determinants across all domains of the ecologic model.

(Am J Prev Med 2016;■(■):■■■–■■■)

JOURNAL OF SPORTS SCIENCES, 2016
http://dx.doi.org/10.1080/02640414.2016.1149605

SHORT COMMUNICATION

Accelerometer data requirements for reliable estimation of habitual physical activity and sedentary time of children during the early years - a worked example following a stepped approach

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ABSTRACT

This study presents a worked example of a stepped process to reliably estimate the habitual physical activity and sedentary time of a sample of young children. A total of 299 children (2.9 ± 0.6 years) were recruited. Outcome variables were daily minutes of total physical activity, sedentary time, moderate to vigorous physical activity and proportional values of each variable. In total, 282 (94%) provided 3 h of accelerometer data on ≥1 day and were included in a 6-step process: Step-1: determine minimum wear-time; Step-2: process 7-day-data; Step-3: determine the inclusion of a weekend day; Step-4: examine day-to-day variability; Step-5: calculate single day intraclass correlation (ICC) (2,1); Step-6: calculate number of days required to reach reliability. Following the process the results were, Step-1: 6 h was estimated as minimum wear-time of a standard day. Step-2: 98 (32%) children had ≥6 h wear on 7 days. Step-3: no differences were found between weekdays and weekend days ($P \geq 0.05$). Step-4: no differences were found between day-to-day variability ($P \geq 0.05$). Step-5: single day ICC's (2,1) ranged from 0.48 (total physical activity and sedentary time) to 0.53 (proportion of moderate to vigorous physical activity). Step-6: to reach reliability (ICC = 0.7), 3 days were required for all outcomes. In conclusion following a 7 day wear protocol, ≥6 h on any 3 days was found to have acceptable reliability. The stepped-process offers researchers a method to derive sample-specific wear-time criterion.

ARTICLE HISTORY
Accepted 28 January 2016

KEYWORDS
Acclererometry; measurement; reliability; young children; physical activity; sedentary time

sports

Article

Reliability and Validity of the Early Years Physical Activity Questionnaire (EY-PAQ)

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Academic Editor: Eling Douwe de Bruin
Received: 8 February 2016; Accepted: 11 May 2016; Published: 26 May 2016

Abstract: Measuring physical activity (PA) and sedentary time (ST) in young children (<5 years) is complex. Objective measures have high validity but require specialist expertise, are expensive, and can be burdensome for participants. A proxy-report instrument for young children that accurately measures PA and ST is needed. The aim of this study was to assess the reliability and validity of the Early Years Physical Activity Questionnaire (EY-PAQ). In a setting where English and Urdu are the predominant languages spoken by parents of young children, a sample of 196 parents and their young children (mean age 3.2 ± 0.8 years) from Bradford, UK took part in the study. A total of 156 (79.6%) questionnaires were completed in English and 40 (20.4%) were completed in transliterated Urdu. A total of 109 parents took part in the reliability aspect of the study, which involved completion of the EY-PAQ on two occasions (7.2 days apart; standard deviation (SD) = 1.1). All 196 participants took part in the validity aspect which involved comparison of EY-PAQ scores against accelerometry. Validty anaylsis used all data and data falling with specific MVPA and ST boundaries. Reliability was assessed using intra-class correlations (ICC) and validity by Bland–Altman plots and rank correlation coefficients. The test re-test reliability of the EY-PAQ was moderate for ST (ICC = 0.47) and fair for moderate-to-vigorous physical activity (MVPA)(ICC = 0.35). The EY-PAQ had poor agreement with accelerometer-determined ST (mean difference = −87.5 min· day^{-1}) and good agreement for MVPA (mean difference = 7.1 min· day^{-1}) limits of agreement were wide for all variables. The rank correlation coefficient was non-significant for ST (rho = 0.19) and significant for MVPA (rho = 0.30). The EY-PAQ has comparable validity and reliability to other PA self-report tools and is a promising population-based measure of young children's habitual MVPA but not ST. In situations when objective methods are not possible for measurement of young children's MVPA, the EY-PAQ may be a suitable alternative but only if boundaries are applied.

Keywords: physical activity; sedentary behaviour; measurement; self-report; preschool; children; accelerometry; ethnicity

Appendix 3. – Systematic review supplementary materials

Appendix 3.1. – Example of search strategy (Pub Med)

PUB MED- Search Strategy – Bingham et al early years correlates review

#1 "physical activity"[All Fields]

#2 "exercise"[MeSH Terms] #3/OR "exercise"[All Fields])

#4 "play"[All Fields]

#5 "physical fitness"[All Fields]

#6 "physical inactivity" [All Fields]

#7 "sedentary"[All Fields]

#8 "sports"[MeSH Terms] #9/OR "sports"[All Fields] #10/OR "sport"[All Fields]

#11 "health behaviour"[All Fields] #12/OR "health behavior"[MeSH Terms]

#13 "motor movement"[All Fields]

#14 "child"[MeSH Terms] #15/OR "child"[All Fields]

#16 "children"[All Fields]

#17 kindergarten[All Fields]

#18 preschool[All Fields]

#19 "early years"[All Fields]

#20 "humans"[MeSH Terms]

#21 English[lang]

#22 "child, preschool"[MeSH Terms]

#23 "infant"[MeSH Terms:noexp]

Appendix 3.2. –Systematic review inclusion/exclusion form

Author & year Today's date:Reviewer:

Question	Yes	Not Clear	No	Further information:
Is the study published in a peer-review journal?				State Journal:
Is the study written in English?				
Is the study an **observational (cross or pro) study / baseline intervention study ?**				State the type of study:
Is the age group studied **preschool mean age<6?**				Mean age of the sample:
Do the participants **attend formal/statuary schooling** ?				
Is **physical activity** measured using quantitative methods? I.e. electronic and/or direct observation				State the primary measure applied (e.g Actigraph):
Is physical activity the main **outcome/dependant** variable?(Total PA; VPA; MVPA)				State Outcome/Dependant variable:
Are associations investigated between **physical activity** and correlates/determinants/factors?				State correlates/determinants/factors:
Are participants unable to be physically active (i.e. disabled or ill)				
Does the sample have a special need or health condition? (asthma, learning difficulties, autism etc).				If yes please state:

IF THE ANSWER TO ANY OF THE ABOVE IS SHADED BOX, EXCLUDE THE STUDY OR DISCUSS WITHIN THE REVIEW MEETING.IF ANY ANSWERS ARE "NOT CLEAR" PLEASE DISCUSS WITHIN THE REVIEWING MEETING

This study is:	**Included**	☐	**Excluded**	☐	**Not sure**	☐
	Details:					

Other information

Appendix 3.3. – Description table of included studies within chapter 3 systematic review.

Study	Design	Country	Aims	Correlates Investigated	Analyses	Sample Demographics	PA Measurement	Measurement Period	Validity and Reliability of PA Measure	Reported PA level	Notes
Sallis et al. (1993)[1]	Cross-sectional	USA	Investigate the different correlates of children's physical activity.	Ethnicity, SES, sex, skinfolds, motor co-ordination, TV hours per week, play rules, mothers activity, familial interaction, parent activity control, convenient play spaces, availability of toys, frequency in play spaces.	Correlations, regression.	n = 347; mean age 4.4 years (SD = 0.5) 201 Mexican American; 146 Anglo-American.	Observation (BEACHES).	4 x 1 hour in home evening visit, 30 min prior to evening meal: coded 1 min.	Inter-observer: agreement was 90%-95%. Reliability was reported for many different measures.	Not reported.	
Adams et al. (2010)[2]	Cross-sectional	USA	Examine the associations of age, sex, weight status and children's proxy reported physical activity levels.	3-4 year olds: sex differences of number of times a week playing outside.	T-tests.	n = 421; mean age 6.4 years (SD 1.2); 3-4 year olds = 21, 5-6 = 240, 7-8 = 138.	Proxy questionnaire.	One screening appointment to complete questionnaire and body measures.	Test-retest reliability was completed for 80 children, r = 0.88.	Playing outside for the whole sample was reported 2-3 hours. For 3-4 year olds only number of times playing outside weekly was reported.	
Anderson et al. (2008)[3]	Cross-sectional	USA	Estimate the proportion of children aged 4 - 11 years who are participating in low levels of active play and high levels of screen time.	4-5 year olds sex, weight status (BMI) stratified by sex and ethnicity.	Wald-chi tests for univariant analyse.	Total sample n = 2964, mean age 8.9 years. Sample was stratified by age. 4-5 year old n = 777, mean age 4.9 years.	Proxy questionnaire, number of occasions a week a child takes part in exercise that causes sweating and hard breathing.	One occasion completing a questionnaire.	Cited sources but no reliability or validity statistics.	Adjusted for study design. Boy's median 6.9 (percentiles 6.3-7.4) times a week active, girls 7.3 (6.2-8.3).	

Yamamoto et al. (2011)[4]	Cross-sectional	Germany	Examine variables associated with every day, objectively measured PA in preschool children.	Age, educational status of parents, immigrant background, number of siblings, child's BMI, Mothers BMI, Fathers BMI, child's general health, child's desire to be active, TV viewing, time spent outside, organised sports, environmental opportunities and parents PA.	Multivariate regression models stratified by sex.	n = 1134, age 3 - 6 years, recruited from 52 preschools.	Actiheart, MVPA.	Monitor worn for 4 days. Minimum requirement was 1 weekday and 1 weekend day. 13.4 mean hours wear time on weekdays, and 12.8 mean hours wear time weekends.	Not reported, no reference.	Not reported.
Williams et al. (2008)[5]	Cross-sectional	USA	Examine the relationship between level of motor skills and PA.	Gross motor skill performance; locomotors skills and object control skills.	Correlations and ANCOVAs.	n = 198, mean age 4.2 years (SD 0.5). 53.5% African American, 34.9% White.	Uniaxial Accelerometer (Actigraph model 7164) - 15 sec epoch, PATE cut point. %of intensity was used. %LPA, %MVPA, %VPA.	Monitor worn for 8-10 days. Mean 12.7 hours.	Acceleromete r validity cited elsewhere. Reliability cited elsewhere. No statistics applied but laboratory work referred to shows near perfect reliability.	Total 90 min MVPA, no report for total PA.

Tanaka et al. (2009)[6]	Cross-sectional	Japan	Evaluate MVPA using tri-axial accelerometer.	Sex.	Student's T-Test.	n = 212, mean age 5.8 years (SD 0.6).	Accelerometer - Tri-axial (ActivTracer), Uniaxial (Life order EX).	Monitor worn for 6 days.	This study is a validation study. Reliability not reported.	13037 step counts/day; boys 13650, girls 12255. Time in MVPA min/day 102; boys 112.3, girls 88.8. Physical Activity Level (PAL) 1.54; boys 1.55, 1.51. Time in PAR ≥ 4 (Physical activity ratio, min/day) 19.9; boys 22.6, girls 16.4.
Vorwerg et al. (2013)[7]	Cross-sectional	Germany	Investigate different variable associations with objective PA.	Sex, weekday's vs weekends, obesity, more time outside, Preschool quiet activities, parent weight status, and screen time.	Wilcoxon test, spearman rank correlation, chi-square test.	119 children, only 92 met all measurement criteria. Boys mean age 5.3 years, girls mean age 5.0 years.	Sense Wear Pro 2 Accelerometer .	Worn for 7 consecutive days, included at least 1 weekend day. Mean daily wear time was, 21.8 hours/day.	Validity cited elsewhere. 1.7% error versus metabolic analyser. Reliability not mentioned.	Mean daily PA was 4.4hours.
Vasquez et al. (2006)[8]	Cross-sectional	Chile	Assess energy intake, energy expenditure and physical activity patterns of obese children at children's centres and at home.	Sex, times of day at children's centre, at home and weekday.	Descriptive, difference tested or non-parametric alternative, Wilcoxon.	24 obese children (12 boys, 12 girls) were selected from first come first serve basis from a group of 252 children's centres. Boys mean age 4.3 years (SD 0.05), girls mean age 4.2 (SD 0.7).	Tritrac-RD Research Ergometer, axial accelerometer.	Three full days (2 weekdays) and 1 weekend day.	Not reported.	Not reported.

Vale et al. (2011)[9]	Cross-sectional	Portugal	Analyse differences in TPA and MVPA of preschool children during school days when children attend the PE class compared with school days without PE.	Sex, physical education class.	Independent t-tests and general linear model (GLM).	193 children, mean age 4.8 years (SD 0.8), from kindergarten.	Actigraph Uniaxial Accelerometer GTM1 model.	Five consecutive days. Monitor was placed and fitted by teachers when the children arrived at school, and removed when leaving.	Validity cited elsewhere. Cut points ranged from r = 0.46-0.70 (Sirard cut-points). Heart rate vs accelerometer r = 0.50-0.74.	Mean daily TPA on Physical education days (PED) was 66.40(SD 22.08) min; boys 70.49(SD 24.28) min, girls 62.28(SD 19.38). Mean daily MVPA on PED days was 26.55 (SD 12.18) min; boys 29.39(SD 13.14) min, girls 24.08(SD 11.11) min. Mean daily TPA on non PED was 55.45(SD 17.17) min; boys 59.14(SD 17.25) min, girls 52.14(SD 16.06). Mean daily MVPA on non PED was 20.16(SD 9.12) min; boys 22.03(SD 9.14), girls 18.27(SD8.28).	
Vale et al. (2010)[10]	Cross-sectional	Portugal	1) Document differences in TPA and MVPA between sexes on weekdays and weekend days. 2) Assess compliance to physical activity recommendations.	Sex, weekdays vs. weekends.	Descriptive, independent samples t-test, general linear model, chi-square comparison tests.	245 preschool children, from kindergartens. Mean age 5.2 years (SD 0.8).	Uniaxial Accelerometer (GTM1-model).	Seven consecutive days, 10 hours of wear time per day. Three weekdays and 1 weekend day was used in the analysis.	Validity reported elsewhere.	TPA mean weekday daily min 143.8(SD 43.3); boys 155.4(SD 45.4), girls 128.2(SD34.8). TPA mean weekend day daily min 123.9(SD41.8); boys 131.59(SD45.7), girls 113.9(SD 33.6).	
Spurrier et al. (2008)[11]	Cross-sectional	Australia	Describe the characteristics of preschool children’s home environment, what may influence children’s physical activity,	Parental physical activity (frequency of walking >30min per day-both paternal and maternal), Mother's frequency of organised sport,	Descriptive and multiple ANOVA's with bonferoni multiple comparison technique.	Out of 516 parents screened during recruitment, 280 agreed to participate in the study (54% response rate). Child mean age 4.8 years (SD 0.21).	Parental questionnaire - outdoor physical activity play.	One home visit.	Validity cited elsewhere.	Not reported.	Only significant results were reported.

			sedentary behaviour and dietary patterns.	presence of playground near home, participation in organised sports, dog ownership.						
Trost et al. (2003)[12]	Cross-sectional	USA	Compare the physical activity levels of overweight and non-overweight 3-to-5 year old children while attending preschool.	Weight status.	Two-way ANCOVA, with sex and weight status as group variables. Parent education was the co-variant. Fisher exact tests and contingency tables were used in group differences.	281 children recruited. After deletions of missing data, sample was 245 children (127 girls; 118 boys) and parents (242 mothers; 173 fathers). 51.1% of parents did not have college education and 60% were African American.	MTI 7164 uniaxial accelerometer (15 sec epochs). Direct observation system for recording activity in preschools (OSRAP).	Children were observed for 1 hour on 3 randomly selected separate days. Accelerometer was worn ranging from 1-11 days. Three days of wear time was selected.	Validity for accelerometer and OSRAP reported elsewhere. ICC for OSRAP was reported as 0.91 - 0.98. Percent agreement for five day activity categorizations was 75% - 99%.	Mean activity rating: males: overweight 2.40(0.20), not overweight 2.60(0.19). Females: overweight 2.50(0.19), not overweight 2.49(0.20). %Time in MVPA: males: overweight 39.0(12.5), not overweight 47.6(12.7). Females: overweight 42.2(12.8), not overweight 41.6(12.5). Total counts/h: males: overweight 50.5(14.4), not overweight 60.0(14.5). Females: overweight 42.2(12.8), not overweight 41.6(12.5).
Hinkley et al. (2012)[13]	Cross-sectional	Australia	Investigate possible correlates of pre-schoolers physical activity across all levels of the socio-ecological model, for boys and girls separately, and	Numerous correlates across the socio-ecological model (individual, behavioural, psychological, social, physical environment).	T-Tests. Generalized linear models (GLM) to test for correlates.	1036 children age 3-5 years from 71 child care centres and 65 preschools. Sample with data completed were 1004 children and parent(s). Final accelerometer sample once wear	Actigraph Uniaxial Accelerometer GTM1 model. 15 sec epoch.	Eight-day accelerometer measurement period. In this period questionnaire and measurements were taken.	Weekday and weekend days together equalled a reliability of (ICC) 0.7. Weekdays = 0.7. Weekend days = 0.61. Correlates	Boys: total week 17.3% in TPA, weekdays 17% TPA, weekends 18.2%. Girls: total week 15.4% TPA, weekdays 15.3%, weekend days 15.8%. Wear time was at least 7 hours. Total week was any 3 weekdays and 1 weekend days.

			differences for weekdays and weekends.			time was applied equalled 705 children.			survey was found to be reliable and is reported elsewhere.		
Hnatiuk et al. (2012)[14]	Cross-sectional	Australia	Describe the current PA levels and patterns of toddlers and to determine compliance with existing Australian PA recommendation s.	Sex, parent educational differences.	Descriptive statistics, one-way ANOVA and chi-square.	Consent from 542 parents was obtained. Complete data set were obtained (including wear time) from 295 children (158 boys, 137 girls) mean age 19.1(SD 2.3) months.	Actigraph Uniaxial Accelerometer GTM1 model. 15 sec epoch.	As part of an intervention, no statement of how long the measurement period was.	Reliability for LPA was 0.7 and MVPA and CPM were 0.80.	Total: LPA 184.5(30.7), MVPA 47.9(16.2), 90.5% met guidelines. Boys: LPA 186.5(31.6), MVPA 49.6(16.3) 91.1% met guidelines. Girls: LPA 182.3(29.7), MVPA 46(16), 89.8% met guidelines.	
Jackson et al. (2003)[15]	Prospective	Scotland	Quantitatively describe levels of habitual PA in 3 to 4 year old children, describe normal developmental changes in PA longitudinally and assess tracking of PA over 1 year.	Sex, weekday vs. weekend, BMI, age, and SES.	ANOVA, student t tests and correlations.	112 subjects originally. Final sample of 104 (52 boys 52 girls) for cross-sectional sample age (boys mean age 3.8 years SD 0.4; girls 3.7 SD 0.4). 60 children (30 boys, 30 girls) were followed up after 1 year.	CSA WAM-7164 accelerometer.	Two weeks.	Cited previously reported.	Boys 777(207) CPM; girls 651(172) CPM.	Prospectiv e
Kimbro et al. (2011)[16]	Cross-sectional	USA	Assess whether activity patterns are associated with weight status and are children's residential contexts associated with activity patterns.	Numerous correlates across the socio-ecological model (individual, behavioural, psychological, social, physical environment).	OLS regression and binomial regression models.	Sample derived from a birth cohort sample. 1975 children with no missing home survey data were included in the analysis. Child mean age 63.5 months (5.3 years).	Self-report (proxy report).	One home visit.	Not reported.	Weekday hours of outdoor play = 2.05(SD 1.89). Days per week mother takes child outside to play = 3.78 (SD 2.18).	

Sigmund et al. (2007)[17]	Cross-sectional	Czech Republic	Examine the age and sex associated differences in PA using energy expenditure in preschool children, teenagers and young adults. To also compare the activity energy expenditure to PA recommendations.	Weekday vs. weekend, sex, and attending kindergarten or nursery.	MANOVA's and correlations.	122 children from 11 kindergartens were recruited. 104 (51 boys) had full complete data. Age 5-7. Data that was previously collected from a further 1961 subjects' age 12-24 years was used to make comparisons across age.	Uni-axial accelerometer to measure total and activity energy expenditure, along with parent/teacher report. Caltrac.	Seven-days.	Not reported.	Girls weekday activity energy expenditure = 12(kcalkg-1day-1), weekend = 12.3(kcalkg-1day-1). Boys weekday activity energy expenditure = 13.4(kcalkg-1day-1), weekend = 14.2(kcalkg-1day-1. Weekday leisure time activity expenditure vs. school activity expenditure (kcalkg-1day-1) was 8.2 vs. 3.8. Weekend leisure time activity expenditure vs. school activity expenditure (kcalkg-1day-1) was 9.5 vs. 3.9.
Smith et al. (2010)[18]	Cross-sectional	Australia	To investigate how parental self-efficacy and perceived barriers are associated with children's PA and screen time and how these relationships differ according to children's age and house-hold socio-economic demographic characteristics.	Sex, age, parent's barriers, region of home, maternal education, and parental self-efficacy of influencing children to be active.	Bivariate analyses (chi-square), multivariate analysis (logistic regression models), Bonfronni adjustments were made for the number of comparisons.	16 preschools and 24 long day care centres were randomly selected. Small children centres with 20 or less children and those that cater for children with special needs were excluded. 764 preschool children, mean age 3.9 years (1.7-5.6 range), 50.3% were boys.	Parental questionnaire - pre-schooler participating in organised PA, participating in non-organised PA. Meeting PA guidelines (3hours of TPA).	One meeting.	Cited elsewhere, Kappa agreement poor to moderate.	Not reported.

Hinkley et al. (2012)[19]	cross-sectional	Australia	1) Identify the percent of time a sample of Australian children spend being physically active 2) Investigate how much time preschool children spend in screen based behaviours 3) Investigate differences in physical activity and screen-based behaviours by sex and age 4) Determine the prevalence of adherence to published recommendations for physical activity and screen-based entertainment in preschool children.	Age, sex.	Generalized linear modelling.	1004 children recruited from 16 child care centres and 16 randomly selected preschools. After wear time criteria the sample was reduced to 703 (388 boys, 315 girls). Mean age was 4.5 years (95%CL = 4.5-4.6).	Actigraph Uniaxial Accelerometer GTM1 model.	Eight day period with some having greater.	Validity reported elsewhere. Reliability for wear time (3weekdays, 1 weekend day) was 0.8.	CPM: total 708.3 (SD 182) ranges 318.3-1469.5. Boys = 730.2 (SD 181.2) range 361.0-1415.0. Girls 681.4 (SD 179.6). %LPA: Total 11.7 (SD 2.4) boys = 12.2 (SD 2.4). Girls 11.1 (2.4). %MPA: Total 3.4 (SD 1.9) boys = 3.7 (SD 2.0). Girls 3.0 (1.6). %VPA: Total 1.4 (SD 0.9) boys = 1.4 (SD 1.0). Girls 1.3 (0.9). %TPA: Total 16.4 (SD 4.2) boys = 17.3 (SD 4.1). Girls 15.4 (4.0).
Gunter et al. (2012)[20]	Cross-sectional	USA	Determine the relationship between family child care homes characteristics and practices using objectively measured PA in 2-5 year olds.	Children's centres that provide 4 or more significant physical activity promoting polices/practices.	Mixed ANOVA's.	56 children's centres were recruited. 45 had completed data. 136 children from the 45 had valid data and took part. 73 boys, 63 girls.	Actigraph Uniaxial Accelerometer GTM1 model.	Wore accelerometers during time at children's centres.	Cited elsewhere.	A children's centres s = 32.3(SE 1.1min/h; Non PPA children's centres = 28.8(1.2).

Blaes et al. (2011)[21]	Cross-sectional	France	Analyse changes in habitual PA of boys and girls from preschool to junior school and assess differences between school days and school free days with high frequency accelerometer.	Sex and PA levels during preschool days vs. school days.	Descriptive and multiple ANOVA's.	362 children for the whole sample. For the preschool children section 94 pre-schoolers (44 boys, 50 girls) mean age 4.4 years.	Actigraph Uniaxial Accelerometer GTM1 model.	Seven days.	Cited elsewhere.	Reported for whole sample only. Preschool children (min per day) LPA = 762 (SD20); MPA 50 (SD 18); VPA 17 (SD 10); VPA+VHPA (very high PA) 28 (SD 17); MVHPA 78 (SD 20).	Boys were more active ($p < 0.05$) then girls across all intensities (LPA, MPA, MVPA, VPA), the sex difference has been reported as Total Physical for this study in the association table, and separately for LPA, and MVPA.
Cardon et al. (2008)[22]	Cross-sectional	Belgium	Determine which environmental factors contribute to PA levels during recess in preschool boys and girls.	Sex, recess variables: no. of children per m2; no. of supervising teachers; aiming equipment; playing equipment; recess duration, type ground surface; playground markings; vegetation; height	Univariate regression analyses. Girls and boys were stratified with single-predictor two-level (school-pupil) model was used. Z Scores were calculated in order to test	415 boys and 368 girls from 39 preschools were randomly selected. Boys mean age 5.2 years (SD 0.4); girls mean age 5.3 years (SD 0.4).	Pedometer-Yamax Digi-walker TYPE SW-200.	Each child wore the pedometer for a familiarization period 90-120 minutes before registration. Each child then wore the monitor (reset to zero) for the duration of recess.	Reported pedometer has 0.73 correlations with accelerometer data.	Boys 65 (36) steps per minute, girls 54 (28) steps per minute.	

				differences; and availability of toys.	for significance of variance.					
Brown et al. (2009)[23]	Cross-sectional	USA	1) Describe physical activity behaviours and accompanying social and environmental events to these behaviours using direct observation. 2) Determine which contextual conditions where predictors of MVPA and none sedentary PA (Total PA) for children during outdoor play during play periods at preschool.	Preschool outdoor context- balls and objects, open space, fixed equipment, wheel toys, socio problems; indicator of activities- children, adults, groups comparison- solitary, one-to-one with peer, group without adults, adult present.	Logistic regressions.	476 children observed outside, 50% boys, 54% African American, 38% European American, mean age 4.2 years (SD 0.7). 372 children observed inside, 51% boys, 52% African American, 40% European American.	Direct Observation. Observational system for recording physical activity in children- Preschool version.	Indoor children were observed for a mean of 327.5 minutes. Outdoor children were observed 34 min per child.	80% Inter-observer agreement. Validation and development detailed elsewhere.	Indoor PA levels were 94% sedentary based, with 1% being recorded as MVPA. Outdoor PA 56% sedentary, 27% light PA and 17% MVPA.
Collings et al. (2013)[24]	Cross-sectional	England	To examine independent associations between a range of accelerometer-derived PA intensities and sedentary time	Sex.	Comparison tests (chi-square, ANOVA, Wilcoxon) correlation and linear regression.	398 preschool children; 202 boys, 196 girls; mean age 4.10 years (SD 0.08).	Actiheart, only accelerometer data is used.	Seven consecutive days.	Reported elsewhere.	TPA (min/d) 423.6 ± 63.0; MPA (min/d) 58.8 ± 28.2; VPA (min/d) 23.6 ± 21.3; MVPA (min/d) 84.7 ± 46.4.

			with body composition.								
Dowda et al. (2009)[25]	Cross-sectional	USA	Examine polices and characteristics of preschools that may influence the time children spend in physical activity and sedentary behaviours.	Playground equipment, playground size, use of electronic media, physical activity promoting polices, number of field trips, number of community organisation visits, teacher PA, time outside, teacher education level, PA opportunities, teacher PA training, children per classroom, and class room size.	Mixed model ANOVA.	20 preschools, 11 commercial, 6 faith based, and 3 head start (government funded for low SES). 299 children, 50% male, 49% black, 42% white.	Accelerometer Uniaxial, Actigraph model 7164.	Two weeks.	Cited elsewhere.	Not reported.	Child care setting, MVPA is outcome variable.
Dwyer et al. (2011)[26]	Cross-sectional, validation study.	Australia	Outline the development and socio ecological framework of the Preschool Physical Activity Questionnaire (PrePAQ) and to report its validity and reliability.	Sex and age.	Comparison tests, Bland-Altman plots and correlations.	67 children for the validity aspect of the study. 52% boys; 3 year olds 27%, 4 year olds 33%, 5 year olds 24% and ethnicity = white 91%.	Three days parent recall questionnaire and uniaxial accelerometer.	Three days with 6 hours accelerometer, uniaxial. Actigraph MTI 7164.	Reported elsewhere.	Reilly cut points = SED (min/hr.) 46.3 (cl: 45.4 - 77.1); TPA (min/hr.) 13.7 (cl 12.9-14.6). Sirard cut points = SED (min/hr.) 48.9 (cl 48.0 - 49.6), LPA (min/hr.) 7.1 (cl 6.6 - 7.5), MVPA (min/hr.) 4.1 (CL 3.6 - 4.6), TPA (min/hr.) = 11.2 (cl 10.3 - 12.0).	LPA, MPA, VPA, MVPA.

Sallis et al. (1988)[27]	Cross-sectional	USA	Identify correlates of PA in very young children with an emphasis on family related variables.	Family CVD risk, parent VPA, father BMI, child BMI, mother BMI, and type A behaviour.	Multiple regression.	33 children, 39% male, 3.9 years (SD 0.7); 45% black 27% Hispanic, 3% white.	Direct Observation - Fargo activity time sampling survey (FATS).	Thirty minute unstructured free-play sessions on the preschool playground during 2 consecutive days.	Cited elsewhere.	58% in light activity (sedentary based), 31% in moderate activity, 11% vigorous activity.	Light activity, moderate activity and vigorous activity were outcome variables in models conducted. But due to light activity meaning sedentary behaviours and vigorous calculations being "unreliable" only moderate results were conducted and hence only included in results table.
Benham-Deal (2005)[28]	Cross-sectional	USA	Examine characteristics of young children's physical activity patterns.	Weekday vs. weekend, and time of day (morning, afternoon, evening).	Paired T-test, repeated measures ANOVA.	39 children (20 girls, 19 boys) mean age 4.3 years (SD 0.7).	Heart Rate monitoring and parental log.	Three days, 2 weekdays and 1 weekend day.	Cited elsewhere, no r-value reported.	Weekday: morning 20.7% MVPA, afternoon 23.5% MVPA, evening 20.7% MVPA. Weekend: morning 23.2%, 23.8%, 15.5%.	

Gubbels et al. (2012)[29]	Cross-sectional	Netherlands	Examine the association of several physical activity facilities in the physical childcare environment with physical activity levels of 2 - 3 year old children during childcare.	Play equipment inside and outside in a childcare environment. Policy assessments.	Cohen's kappa, t-test, backward regression analyses and step-wise multilevel linear model analyses with 3 levels.	175 children from 9 preschools, 89 (50.9% -boys), mean age 2.6 years.	Direct observation - Observational system for recording physical activity in children - preschool version (OSRAC-P).	Fifteen second observations followed by 30 seconds recording multiplied by 4 over 3 minutes multiplied by 2 for each child.	Validity cited elsewhere, Inter-rater reliability = 0.7.	5.5% of indoor PA = MVPA; 59.4% sedentary behaviour indoor. Outdoor = 21.3% MVPA, 31.2% sedentary.	Childcare setting.
Grigsby-Toussaint et al. (2011)[30]	Cross-sectional	USA	Examine whether living in neighbourhoods with high levels of greenness is associated with PA levels of pre-schoolers.	Neighbourhood greenness, sex, parental support (spending time playing with child), and parental education.	Linear regression.	33 day centres across five counties in central Illinois. 90% (30 centres) took part. Sample = 365 children age 2-5 years.	Parental proxy report for outdoor PA.	Parents asked question once.	Reported elsewhere.	Mean average 60 minutes of outdoor play.	Childcare setting.
Fernald et al. (2008)[31]	Prospective	Mexico	Explore the associations between maternal depressive symptoms and physical activity of children aged 4 to 6 years.	Maternal depressive symptoms - depressed mood, loss of interest and/or pleasure in activities, fatigue, feelings of excessive guilt and/or worthlessness, sleep and appetite disturbances and social difficulties, child age, sex, mothers age, family SES, child TV viewing, maternal PA, child weight status, and	Comparison tests, logistic regressions.	Mothers and children were originally recruited as part of a RCT. A sub sample of the RCT (n = 242) was used with this study. The first measurements were taken at 15months of age and then again at age 4-6 years.	Parental proxy report - international physical activity questionnaire.	Questions answered at 15 months and then at 4-6 years of age of the child.	Cited elsewhere.	30% of mothers reported that children had low activity (less than 20 minutes) 7 days a week.	Prospective

				maternal weight status.						
Baranowski et al. (1993)[32]	Prospective	USA	Investigates whether physical activity varies by physical environment and other demographics.	Age, ethnicity, sex, and weather.	Mixed ANOVA.	191 children, 90 boys, 101 girls, age 3-5 years, Anglo-American, African American, and Mexican American.	Direct observation - Children activity rating scale (CARS).	Four days per year for 3 consecutive days.	Validity cited elsewhere. Reliability: 97% interobserver agreement in PE classes and 84% in open field observations.	Low 2 on scale of 1 - 5.
Beets et al. (2008)[33]	Cross-sectional	USA	Examine effects of father-child involvement and neighbourhood with young children's PA.	Sex, weight status, motor skills, parental education, family support for sports, father and child time, parental perceived neighbourhood safety, ethnicity, TV viewing, mothers education, no siblings, poverty status, father work	Multi-level modelling.	10,694 children, boys = 5454, girls = 5240, age 5-6 years, white 67.1%, Hispanic 16.6%, African American 7.1%, Asian 4.5%.	Parental proxy questionnaire.	1998-1999 - national survey.	Cronbachs' reliability = 0.74.	Four questions with rating scale being 0 to 7. 0 lowest 7 highest. Q1 - Structured activity = boys 2.2 (SD 0.50), girls 2.2 9SD 0.50); Q2 Free activity boys 2.2 (SD 0.52), girls 2.2 (SD 0.53); Q3 Aerobic activity boys 2.1 (SD 0.51), girls 2.1 (SD 0.52); Vigorous activity boys 4.2 (SD 2.24), girls 3.7 (SD 2.24).

				status, and mother work status.							
Bellows et al. (2013)[34]	RCT - baseline	USA	To test the efficacy of the intervention.	Weekday vs. weekend day PA at baseline.	T-test.	201 children, age 4.4 years.	Pedometer.	Parents place pedometer on the child on 6 days (4 weekdays and 2 weekends).	Cited in reference section but no mention.	9,509 (SD 3,599) mean daily step count.	
Boldemann et al. (2006)[35]	Cross-sectional	Sweden	Study the impact of different preschool environments upon children's spontaneous physical activity and sun exposure.	Environment category, sex, and age.	T-test, correlations, linear mixed models.	11 preschools - 197 children, age 4-6 years.	Pedometer - Yamax digi-walker SW-200.	Twelve days.	Cited elsewhere.	Step/min 21.5; girl's step/min range 8.9 - 30.0; boy's range 8.8-37.2.	Childcare setting.
Bower et al. (2008)[36]	Cross-sectional	USA	Determine the relationship between the social and physical activity environment in childcare centres.	Activity opportunities, port play environment, PA training and education, fixed play environment, and sedentary environment.	Correlations, ANOVA, ANCOVA, comparison texts, regression analyses.	20 children centres, 33% black, 59% white, 4% Hispanic, 80 children were enrolled across the 20 centres.	Direct observation - environment and policy assessment for childcare instrument (OSRAP).	Three day period.	Intra-class correlations between observers are 0.90; percent of agreement ranged from 75% to 99%.	15% of monitored period was MVPA; 55% classified as sedentary. Mean Activity level was 2.55 (0.22). Scale was 1 = stationary/motionless, 2 = stationary/movement of limbs, 3 = slow/easy movement, 4 = moderate movement, 5 = fast movement.	Childcare setting.

Brown et al. (2010)[37]	Prospective	Australia	Assess if children's lifestyle behaviours at 4-5 years or 6-7 years are associated with their weight status	TV viewing.	Four path models.	Two waves. Wave 1 children 4-5 years, Wave 2 children aged 6-7 years. The study was an obesity outcome paper, but did test the association between PA and TV viewing, 2560 children (4-5 years), boys 52.3%.	Parental Diary.	Two 24 hour dairies for randomly selected weekday and weekends.	Not reported.	Wave 1 children aged 4-5 years = 72 min (average), MVPA 2.1 hours/days.
Burdette et al. (2005)[38]	Cross-sectional	USA	Expand whether higher prevalence of obesity, spend less time playing outdoors and spend more time watching TV when living in neighbourhoods mothers perceived to be unsafe.	Weekday vs. weekend, and mothers perceived neighbourhood safety.	T-tests, ANOVA.	Birth cohort study (n = 3141), 20 large cities. Mean age 39 months, 53% boys, 35% lived in low poverty households, 50% non-Hispanic black, 25% non-Hispanic white, 25% Hispanic.	Parental recall of outdoor play - 1 question on weekdays, 2nd question on weekends.	Survey.	Cited elsewhere.	Outdoor play weekday = 156 (SD 120). Weekend = 26 (SD 149).
Burdette et al. (2004)[39]	Cross-sectional	USA	Compare direct measure of PA in preschool-aged childcare with 2 parental-report measures of children's outdoor play time.	Season, TV, and sex.	Correlations.	250 preschool children, 44 months, 87.7% white, 12.35 black, 57% boys.	Accelerometer Uniaxial and parental recall. Used accelerometer as more superior method. RT3 Triaxial.	Three days for every waking minute.	Cited elsewhere.	Total PA = 667 (SD 186); Boys 693 (SD 184), Girls 630 (SD 183).

Burgi et al. (2011)[40]	Prospective	Switzerland	Investigate the relationship of objectively measured PA with motor skills, aerobic fitness and %body fat in young children.	Sex, aerobic fitness, gross motor skills, and % body fat.	Mixed linear models.	217 children, 4-6 years (mean age 5.2 years (SD 0.6)), 48% boys.	Accelerometer uniaxial, GT1M Actigraph.	Three days of recording (2 weekdays, 1 weekend days) minimum 6 hours.	Reported r = 0.82 between VO2 max + Actigraph counts/epoch 6 hr. validity was highly correlated with 10hr validity r = 0.92 P < 0.001.	Not reported.
Bürgi et al. (2010)[41]	Cross-sectional	Switzerland	Assess the differences in adiposity, objectively measured PA, sedentary behaviour and agility performance in preschool children according to different determinants.	Ethnicity, parental education, work status, and region of country.	Comparison tests, regression models.	40 preschools; (n = 542) 20 in German speaking part of Switzerland, and 20 in French part of Switzerland.	Accelerometer uniaxial, GT1M Actigraph.	Three days of recording (2 weekdays, 1 weekend days) minimum 6 hours. Mean wear time = 10.8 hour/day.	r = 0.82 for validity between accelerometer and V02max.	German speaking preschool = TPA 771 (SD 169); MVPA 400 (SD 100). French speaking preschool TPA = 684 (SD 151); MVPA = 361 (SD 101).
Buss et al. (1980)[42]	Cross-sectional	USA	1) Examine the ordinal consistency of activity level across time using 2 different methods of measurement. 2) Examine the relationship of these two measurement methods.	Sex, IQ, and personality.	Correlations.	129 children (65 boys, 64 girls) 3-4 year olds.	Actometer modification of a winding watch.	Wore on wrist for two hours for 3 days.	r = 0.86 at 3 years and r = 0.62 at 4 years.	Not reported.

Cardon et al. (2008)[43]	cross-sectional	Belgium	Describe accelerometer-based physical activity levels in 4 and 5 year old children.	Sex, age, weekday vs. weekend, and different preschools.	Comparison tests, ANOVA.	Five random preschools, 76 children; boys 37, mean age 5.01 years (SD 0.6); girls 39, mean age 4.95 years (SD 0.5).	Accelerometer uniaxial, Actigraph model 7164.	Four days, 2 weekends and 2 weekdays, minimum wear time 6 hours.	Cited elsewhere.	TPA = 701 cpm (SD = 74), 120min TPA.
Caroli et al. (2011)[44]	Cross-sectional	Denmark, Italy, Poland	Assess preschool children's physical activity habits in three different European countries.	Three different countries, Denmark, Italy and Poland.	Comparison tests.	Denmark 325 - boys 171, girls 154 mean age 50.7 months (SD 10.8); Italy 471 - boys 261, girls 210 mean age 61.4 months (SD 10.4); Poland 298- boys 154, girls 144 mean age 57.8 months (SD 16.7); total sample was 1094 children.	Parent proxy report.	Parents asked a series of questions on one occasion.	Not reported.	Playing outside home during weekdays and weekend, yes or no. Weekday = Denmark children 22.7% yes, Italy children 35.7% yes, Poland children 35% yes. Weekend = Denmark children 11.8% yes, Italy children 22.1% yes, Poland children 7.9% yes.
Chuang et al. (2013)[45]	Cross-sectional	USA	Evaluate ethnic differences in the home physical activity and screen time environment of pre-schoolers enrolled in head start.	Ethnicity.	Mixed model linear and logistic regression.	706 pre-schoolers, 54% Hispanic, 46% African-American.	Parental proxy report - health home survey.	Questionnaire completed once.	Validity cited elsewhere, reliability 55.6% - 95.6%.	0-2 a week PA over 30min = 6.91%.
Lawrence et al. (1991)[46]	Cross-sectional	Gambia and Scotland	Determine whether Gambian children are relatively inactive compared to UK children in the UK and whether this is related to	Nationality/region, age, weight status, and illness.	Kruskal-wallis, mann-whitney U Test.	Gambia, 81 children (39 boys, 42 girls). Scotland, 21 boys and 32 girls. Measured children at 6month, 12 months and 18months.	Activity diary and direct observation.	One day for Gambian children. Field worker every 2.5 minutes in Gambia. No field worker to assess PA in the Scottish children, mother did this role.	Not reported.	Scotland children = 5 hour/day playing; Gambian children spent 1.5-2.5 hour/day playing.

			their poorer nutritional status.					Instead of 1 day, 5 days every measurement every 10 minutes by mothers.		
Davies et al. (1995)[47]	Cross-sectional	England	Investigate the relationship between levels of physical activity and body fatness in a group of preschool children.	Body fat.	Correlation, regression.	77 children, boys mean age 3.09 years, girls mean age 3.08 years.	Doubly labelled water.	Single urine sample was collected before the administration isotope. Urine samples taken every day for 10 days.	Validity was cited.	Boys PAL = 1.44 (SD 0.31), Girls PAL = 1.40 (SD 0.27).
Cliff et al. (2009)[48]	Cross-sectional	Australia	Examine the cross-sectional relationship between process-measured fundamental movement skills and objectively measured habitual PA, and if the relationship differs by sex and FMS sub domain, fundamental movement skills.	Age, sex, BMI, object control scores, gross motor quotient. Stratified by sex.	Comparison tests, correlations and regression models.	138 children from 11 children's centres - final sample was 25 boys and 21 girls, mean age 4.3 years (SD 0.7).	Accelerometer uniaxial, Actigraph 7164 model.	Seven day monitoring, 3 days with min wear time of 6 hours.	Cited elsewhere.	MVPA = 23min for the whole sample.

Cox et al. (2012)[49]	Cross-sectional	Australia	Explore the relationships between preschool children's TV habits, physical activity and their BMI.	Energy intake whilst watching TV, servings of obsegenic foods, BMI, TV viewing weekday, TV viewing weekend, commercial viewing, and non-commercial viewing.	Correlation.	135 children, mean age 4.5 years (SD 0.84), 60% girls, 3.7% obese, 85.2% not overweight or obese.	Parental questionnaire – PrePAQ.	One of subjective measure.	Cited elsewhere.	Three day average - LPA (57.5 (SD 37.4), MVPA (104.1 (SD 60.4).	
Dowda et al. (2004)[50]	Cross-sectional	USA	Determine if physical activity levels of preschool children vary with differences in polices/practices and overall quality of preschools.	No. of field trips, teacher education, time outdoors, free time, type of preschool, class size, computer use, and preschool quality.	Mixed model ANOVA.	Nine preschools were randomly selected. Three types of preschool; private, church-related and head start (government funded). Three from each type were selected. 266 children were observed, 126 males, 140 females, 62.4%African-American, and 32.7% White.	Direct observation (OSRAP).	One hour - 2 to 3 days - 15 seconds observations.	ICC = 0.91 - 0.98.	%MVPA in childcare = 5-8%, %MVPA Outside = 26-29%.	Childcare setting.
Eriksson et al. (2012)[51]	Cross-sectional	Sweden	Study the development of body composition during early childhood between physical activity and body fat.	Total Body fat.	Comparison tests, correlations and linear regressions.	44 children, 23 boys and 21 girls mean age 1.5 years.	Doubly labelled water.	Two urine samples were collected and handed in by parents to a measurement session. Child given stable isotope and had seeping metabolic rate measured by	Not reported.	Physical Activity level SMR (total energy expenditure / sleeping metabolic rate) = 1.44 (SD 0.77) girls 1.35 (SD 0.16) boys, and 1.39(SD 0.17) all.	

								indirect calorimetry.		
España-Romero et al. (2013)[52]	Cross-sectional	USA	Examine the association between objectively measured sedentary behaviour and moderate to vigorous physical activity (MVPA) with body mass index and waist circumference in preschool children.	Sex.	Comparison tests, linear regression (MVPA was used as an independent variable in regressing models).	357 children, 183 boys, mean age 4.5years (SD 0.4). 174 girls, mean age 4.6 years (SD 0.3), 44.8% African American, 37.7% white.	Accelerometer uniaxial, GT1M Actigraph, GT3 Actigraph.	Five days, 2 weekdays and 1 weekend day, at least 6 hours required.	Not reported.	Boys MVPA (min/h) = 8.2 (SD 2.2) ; Girls MVPA (min/h) = 7.3 (SD2.0)
Finn et al. (2002)[53]	Cross-sectional	USA	Identify factors associated with physical activity in young children.	Age, childcare centre, season, sex, BMI, preterm birth, participation in organised sports, parental BMI, and parental education.	Regression models.	214 children, 106 boys, mean age 3.95 years (SD 0.06). 108 girls, mean age 3.90 years (SD 0.06).	Accelerometer uniaxial, model AW16.	48 hour period.	Subsample of 40 was measured using direct observation CARS. Comparison between CARS and accelerometer was r = 0.74.	Girls TPA (CPM) = 26,000.3 (SD = 0.7), girls day time PA (9am-5pm) = 14,000.1 (SD 0.5), girls %VPA = 4.5 (SD 0.2). Boys TPA (CPM) = 28,000.5 (SD = 0.8), boys day time PA (9am-5pm) = 15,000.3 (SD 0.5), boys %VPA = 4.5 (SD 0.2).
Firrincieli et al. (2005)[54]	Cross-sectional	USA	Investigate the association between physical activity and wheezing among a population of inner city children enrolling in head start.	History of wheezing.	ANOVA.	54 children, mean age 3.7 years, 61% girls, 77.8% African-American, 5.5% white, 4 Hispanic (7.4%).	Actiwatch.	Six-7 days.	Not reported.	Wheezers = 607 Count (TPA), non-wheezers = 695 counts (TPA).

Fisher et al. (2005)[55]	Cross-sectional	Scotland	To test the relationship between objectively measured habitual PA and fundamental movement skills.	Sex and fundamental movement skills.	Correlations, comparison tests.	482 children randomly selected from a cohort of 545. 394 children were the final sample. Mean age 4.2 years (SD 0.5).	Accelerometer uniaxial, 7164 Actigraph.	Six days.	Validity cited, reliability not reported.	CPM (TPA) = 769 (SD 192); %LPA = 20.3% (SD 5.3); %MVPA = 3.4% (SD 2.2).
Gagne et al. (2013)[56]	Cross-sectional	Canada	Verify whether psychosocial variables of day-care workers influence pre-schoolers physical activity in day care centres and determine how these variables combine with other factors to explain children's physical activity.	Day care workers theory of planned behaviour variables (intention, perceived behaviour, descriptive norm and past behaviour), and sex.	Multi-level modelling.	242 children, 46 educators from 20 childcare centres. Median age is 4 (3-5), age of day care workers = 35 (21-54).	Accelerometer uniaxial, 7164 Actigraph.	Four days measured. Children needed 2 days with at least 2 hours of data each day.	Validity cited elsewhere, reliability = 2 days ICC = 0.92, 4 hours = 0.89.	53 min (SD 23.55) TPA during childcare.
Grontved et al. (2009)[57]	Cross-sectional	Denmark	Identify and distinguish independent associations between personal and demographic characteristics and physical activity levels in 3-6 year old children attending preschool.	Sex, age, individual preschool/childcare, location, and PA promoting polices.	Mixed models, multiple linear regression models.	146 children, 66 boys, 80 girls. Age 3-6 year olds.	Accelerometer uniaxial, 7164 Actigraph.	Five consecutive days at preschool.	Validity cited, reliability not reported.	MVPA boys = 19.9% in child care, MVPA girls = 15.7% in child care. TPA in child care boys = 260.5 counts/15secs, girls 205 counts/15secs.

Gubbels et al. (2011)[58]	Cross-sectional	Netherlands	Examine the influence of the social and physical child-care environment on physical activity intensity in 2-3 year olds.	Age, positive prompts by staff, positive prompts by peers, sex, and group size.	T-tests, multilevel linear models.	175 children 89 boys (50.9%), 75 two year olds (42.9%), 100 three year olds (57.15%).	Direct observation during child care (OSRAC-P).	15 second observations followed by 30 seconds to record. This was repeated 4 times over a period of 3 minutes for each child.	Not reported.	5.5% of indoor time was spent in MVPA and 21.3% of outdoor PA was spent in MVPA.
Heelan et al. (2006)[59]	Cross-sectional	USA	Provide additional information on the associations between physical activity and body composition among children aged 4-7 years old.	BMI, Body %, fat free mass.	T-tests, correlations.	100 children (52 girls, 48 boys) 87% white, mean age 5.8 years (SD 1.3).	Accelerometer uniaxial.	Seven days, 3 weekdays, 1 weekend day, 8 hours.	Citations but not mentioned.	TPA (CPM) = 820.6 (SD 219.1), MVPA = 273.8 (SD 59.1).
Iannotti et al. (2005)[60]	Prospective	USA	Determine if there is a relationship between mother's PA and child's PA.	Mother's PA.	Autoregressive models.	149 children, mean age 4.4 years (SD 0.5) 82 boys, 67 girls (total n = 149).	Direct observation.	60min observation period at home, 25 seconds observations and 35 seconds for recording.	Validity is cited, Inter-observer agreement for PA = average 95%.	Not clear.
Jago et al. (2005)[61]	Prospective	USA	Examine whether variables affect PA is a triathic-cohort over a 3 year period.	Sex, TV viewing, ethnicity, parental encouragement.	ANOVA, paired t-tests.	149 children, 73 boys 76 girls, mean age 4 years (SD 0.6) 37% African-American, 37% white, 26.6% Hispanic.	Direct observation - CARS, heart rate monitoring.	Six-12 hour observations same time as heart rate monitoring.	Reliability of heart rate cited elsewhere. The validity of heart rate and validity and reliability of direct observation tool not mentioned.	Baseline MVPA = 7.6min/hour (SD 4.2min).

Janz et al. (2005)[62]	Prospective	USA	Examine the tracking of PA and sedentary behaviour in relation to adiposity during middle childhood.	Sex.	ANOVA, correlations.	Baseline = 378 children (176 boys, mean age 5.6 years (SD 0.5); 202 girls, mean age 5.7 years (SD 0.5).	Accelerometer uniaxial.	Four consecutive days including weekend days, at least 8 hours on 3 days.	Cited elsewhere.	Baseline: boys TPA (CPM) = 782 (SD 164), boys VPA = 37(SD18) min.day-1; boys MPA 267(43) min.day-1. Girls TPA (CPM) = 719 (SD 159), girls VPA = 29 (SD48) min.day-1; girls MPA 262(43) min.day-1.
Janz et al. (2004)[63]	Cross-sectional	USA	Investigate the association between physical activity and bone structural measure of proximal femur.	Sex.	T-tests, correlations.	218 boys, mean age 5.2 years (SD 0.4); 249 girls, mean age 5.3 years (SD 0.4); total group was n = 467. 96% White.	Accelerometer uniaxial, questionnaire.	Four consecutive days including 1 weekday, 8hours on 3 days.	Three day reliability r= 0.67 (CL = 0.59 - 0.74), validity is cited for accelerometer . Reliability for questionnaire was r = 0.70 (CL 0.56 - 0.80), validity cited elsewhere.	MPA; boys = 267 (SD 44) midway, girls 262 (SD 44) midway. VPA: boys 38 (SD 19) midway, girls 28 (SD 14) midway.
Kambas et al. (2012)[64]	Cross-sectional	Greece	Examine the relationship between motor proficiency and pedometer determined PA.	Gross motor skills and sex.	Correlations, ANOVA + post hoc tests.	232 children (114 girls. 118 boys) recruited from 30 randomly selected kindergartens in north Greece. Mean age 5.4 years (SD 0.28).	Pedometer, Omron walking Style Pro. HJ-720It-E2.	Wore pedometer for 7 consecutive days.	Cited elsewhere.	Aerobic walking time = 12.8 (SD 17.5). Step.day-1 = 7676 (1893), Aerobic steps days 1486 (1995).
Kelly et al. (2006)[65]	Cross-sectional	Scotland	Test the hypothesis that habitual PA is associated with SES in young Swedish children.	Age, sex, ethnicity, BMI, and SES.	ANOVA, ANCOVA, backward stepwise multivariate model.	339 children, mean age 4.2 years (SD 0.3), BMI 0.40 (SD 0.89).	Accelerometer uniaxial.	Six days, 6 hours of accelerometer over 6 days.	Cited elsewhere.	3% in MVPA (>3200CPM).

Klesges et al. (1990)[66]	Cross-sectional	USA	Examine demographic, environmental and parent -child correlates of physical activity.	Sex, BMI, familial interaction, time outdoors, parental OW, parental encouragement, and parental discouragement.	ANOVA, regression.	222 children, 3-6years, 4.4 years (0.5) 46% upper-middle class, 35% overweight and 29% parents overweight.	Direct observation, SCAN CATS.	One hour late afternoon-early evening, 10second observation followed by 10 second recording.	Inter-rater reliability was 0.91 (0.83-1.00). Validity not cited.	Not reported.	
Kuepper-Nybelen et al. (2005)[67]	Cross-sectional	Germany	Investigate the prevalence of overweight according to nationality and establish determinants responsible.	Ethnicity.	Multiple logistic regressions, odds ratios.	1974 children, 990 boys and 989 girls aged 5-6 years.	Parent proxy report - no. of times in organised sport/played outside.	Recall for 1 week.	Not reported.	58% of German children do sports or play outside at least once a week or less.	
LaRowe et al. (2010)[68]	Cross-sectional	USA	Report the baseline dietary intake and physical activity in preschool aged children in rural American Indian communities.	BMI.	Comparison tests.	135 children, 52.6% boys, 47.45% girls, 94% American Indian.	Accelerometer – Tri-axial, Actical.	Waking hours for 5 days, mean wear time = 4.0 (SD 1.9 days).	Not reported.	Two-3 year olds MVPA = 14.5 (SD 1.6 minutes) min/day. Four-5 years olds MVPA = 19.2 (SD 2.0) min/day.	LPA results for 2-3 years and 4-5 years were in the same direction so results were included as one sample.
Loprinzi et al. (2013)[69]	Cross-sectional	USA	Examine the influence of various hypothesized parental influence variables on children's physical activity.	Parental practices.	Correlations, multivariate regression.	176 children, mean age 4 years (SD 1.3). 46.8% boys, 89.1% white.	Online survey - parental proxy report. Physical activity and exercise questionnaire for children, PAEC-Q.	Recall.	Reliability is not reported. Validity for weekday PA = r = 0.35; weekend PA = r=0.33 both P<0.05.	PA hours per week was reported as 8.2 (SD 2.6) hours a week.	If association of weekday and weekend were the same, one result was documented.

Loprinzi et al. (2013)[70]	Cross-sectional	USA	Examine adherence to current active play and electronic media use guidelines in a sample of US preschool-age children and to examine differences across sex and parental education.	Sex, parental education level, and media use.	ANOVA, chi-square test, logistic regression - odds ratio.	1674 children, 44.5% boys. Mean age 4.0 years (SD 0.1).	Proxy reported, PAEC-Q.	Recall.	Reliability is not reported. Validity for weekday PA = r = 0.35; weekend PA = r=0.33 both P<0.05.	Active play weekday (hours/day) = 3 (SD 0.2), boys 3.0 (SD 0.2), girls 3.1 (SD 0.3). Active weekend (hour/day) 3.7 (SD 0.2), boys 3.6 (SD 0.3), girls = 3.7 (SD 0.2).	
Loprinzi et al. (2010)[71]	Cross-sectional	Australia	Examine the hypothesis that parents with favourable orientations towards PA will provide level of support for PA which in turn results in greater participation in PA.	Parental support, parental perception of competence of child's ability, parent activity, age, and sex.	Observed variable path analysis.	156 children and parents, 51.9% boys, mean age 3.7 years (SD 0.8), BMI = 16.8 (SD 2.2) 30.8% overweight/obesity.	Parental proxy report for home PA, accelerometer uniaxial for child care PA.	2.4 (SD 0.7) days of wear time and 5.5 (SD 0.5) average hours of wear time.	Validity cited, reliability not reported.	Home PA questionnaire (scale 1-7): boys 3.0 (2-5), girls 2.9 (2-3.6). Child care objective MVPA: boys 9.3 (SD 3.9) mins/day, girls 9.0 (SD 3.2).	
Louie et al. (2003)[72]	Cross-sectional	Hong Kong	Investigate trends of physical activity among children aged 3, 4, and 5 using pedometry in preschools.	Age, sex, play space, BMI, and urban housing.	Descriptive, correlations comparison tests, ANOVA.	148 children (86 boys-62 girls), mean age 4.2 years (SD 0.9) from 3 different preschools, rural, Newtown, established town.	Pedometer and CARS.	PA is measured within a 25 minute physical activity class.	Subsample wore pedometers on both left and right hip, no significant difference was found. CARS inter-observer agreement was 96%.	Boys 1470 (SD 638) steps, girls 11147(SD 544) steps.	Child care setting.

Marino et al. (2012)[73]	Cross-sectional	USA	Determine the amount of time low income US preschool aged children spend playing outdoors at home and at school.	Ethnicity, yard near home, region of preschool, playground, mothers education, sex, age, single parent, weight status, full day childcare, half day child care, and region of country.	Logistic regression, linear regression, comparison tests.	National representative survey - 2529, mean age 4.4 years (4.3 - 4.5) 51.1% boys, 22% White, 35.7% Hispanic, 33.1% Black.	Proxy report - parent interview for playing outside at home, teacher interview playing outside in childcare.	Both parents and teachers interviewed.	Not reported.	37.5% 2h< playing outside at home, 40.6% 1.2h < playing outside at home. Teacher reported that children spent 36.3 (33.5-39.1) min/day.	Home and child care setting separate.
McKee et al. (2005)[74]	Cross-sectional	Northern Ireland	Validate a pedometer using direct observation and investigate activity levels in young children.	Sex.	Comparison tests, linear regression, and multilevel modelling.	30 children (13 boys, 17 girls).	Pedometer (Digiwalker) and CARS.	One hour within childcare/preschool (61.4 min).	Reliability- each child was recorded and analysis of CARS took place. The agreement between observers was 83%. Validity was cited.	CARS score was 1.7 (SD 0.59), boys 66.8(SD 64.0) steps, girls 47.4 (SD 61.3) steps.	Child care setting.
McKee et al. (2012)[75]	Cross-sectional	Northern Ireland	Examine the influence of season and age on objectively measured PA.	Season, father's daily play, access to safe place to play, weekday vs. weekend, and sex.	ANOVA, t-tests, correlation.	85 children (52 boys) 3-4 years of age.	Pedometer, digiwalker DW-200.	Six days (4 weekdays and 2 weekend days) 9 hours of measurement on 3 weekdays and 1 weekend day.	Not reported.	Winter boys = 9790 steps, girls 8656 steps. Spring boys = 11,417 steps, girls 11,064 steps.	
Metallinos-Katsaras et al. (2007)[76]	Cross-sectional	USA	Determine the association between PA and BMI among diverse low-income pre-schoolers.	Sex and BMI.	Linear model regression, logistic regression, odds ratio.	56 children, 30 girls 26 boys. 30.4% African-American, 32.2% Hispanic, 21% White, 23.2% BMI 95th< percentile.	Accelerometer.	Seven consecutive days, 4.5 days, Average wear time was 6.6 days.	Validity cited, reliability not reported.	TPA boys = 685.5 (SD 62.8) min/daily, TPA girls 682.2 (SD 81) min/daily, VPA boys = 29.5 (SD 15.1) min/daily, VPA girls = 20.1 (SD 11.3).	

Mickle et al. (2011)[77]	Cross-sectional	Australia	Determine whether plantar pressure distributions generated by preschool children were correlated with objectively measured time spent in PA and sedentary behaviour.	Sex and peak plantar pressure.	Comparison tests, correlations.	33 preschool children mean age 4.3 years (SD 0.6), 17 boys.	Accelerometer Actigraph 7164 uniaxial.	Seven days, 6 hours on at least 3 days.	Validity cited, reliability not reported.	TPA (CPM): boys 911 (SD 254), girls 809 (SD 133); %LPA: boys 13.1 (SD 4.2), girls 11.8 (SD 3.5); %MVPA: boys 6.0 (SD 4.5), girls 3.9 (SD 2.5).
Montgomery et al. (2004)[78]	Cross-sectional	Scotland	Assess relations between total energy expenditure and physical activity level measured using doubly labelled water during engagement in different intensities of PA measured by accelerometer.	Sex, age, and sedentary behaviour.	Correlations, multiple regression.	104 children, 52 boys, 52 girls, 4-5 years, 36 in preschool, 68 in school.	Accelerometer (CSA uniaxial) and doubly labelled water.	Waking hours, 3 days for preschool, 7-10 days for primary. Median 30.3 hours measured in preschool children, 78.3 hours in school children.	Reliability cited, validity not reported.	TPA (CPM): boys 848 (398-1328); girls 719 (332-1154); %MVPA: boys = 4 %(1%-14%); girls 3% (0-8%).
Moore et al. (1991)[79]	Cross-sectional	USA	Determine the relationship between activity levels of parents and children.	Parental PA.	Contingency table, odds ratio.	100 children, 63 boys, 37 girls, 4-7 years.	Accelerometer uniaxial for both children's and parent's PA.	Ten hours/day for children 8.6 hours for 1 day. 8.3 hours for mothers and 7.7 hours for fathers.	Validity = r = 0.35 and reliability is cited.	Not reported.
Niederer et al. (2012)[80]	Cross-sectional	Switzerland	Investigate whether BMI-group related differences in physical activity fitness and PA were present in	Age, sex, and BMI.	ANCOVA.	613 children, mean age 5.2 years (SD 0.06), 49.8% girls and 20.1% overweight.	Accelerometer uniaxial, GT1M Actigraph.	Two weekdays and 1 weekend day. Mean wear time was 10.9 hours/day.	Correlation between 6 hours wear time and 10 hours wear time was r=0.92	TPA (CPM) = Age 4 years, normal weight 712 (SD 139); overweight 728 (SD 153). Age 5 years, normal weight 7402 (SD 181); overweight 682 (SD 130). Age 6 years, normal

			4-6 year old children.						(p<0.0001). Validity reported as r=0.82.	weight 745 (SD 165); overweight 704 (SD 167).	
O'Dwyer et al. (2012)[81]	Intervention study-baseline	England	Investigate the effect of a family focused intervention on preschool children's physical activity.	Sex.	Correlations, step wise backward regression, multi-level modelling.	58 families from 24 sure-start children centres. Baseline – mean age 3.8 years (SD 0.6), 51.9% male.	Accelerometer uniaxial, GT1M Actigraph.	Three days including 1 weekend day, 521 min weekday, 483 min weekend.	Validity cited, reliability not reported.	TPA weekday = 113.2 (SD 24.9), TPA weekend = 101.6 (SD 30.1).	
O'Dwyer et al. (2011)[82]	Cross-sectional	England	Compare activity levels of overweight and non-overweight preschool children.	Weight status.	T-tests.	50 children, mean age 4.4years (SD 0.5), 54% Boys.	Accelerometer Uniaxial, GT1M Actigraph.	Seven days worn, wear time = 3 days (2 weekdays, 1 weekend day).	Validity cited, reliability not reported.	MVPA weekday: OW boys 38.6 (SD 18.1); non-OW boys 45.2 (SD 20.3); OW girls 38.0 (SD 10.5); non-OW girls 43.3 (SD 17.0). MVPA weekend: OW boys 34.0 (SD 11.9); non-OW boys 58.0 (SD 10.4); OW girls 28.9 (SD 9.5); non-OW girls 42.2 (SD 26.4).	Weekday and weekend results were combined if in the same direction (MPA, VPA = MVPA).
Oliver et al. (2010)[83]	Cross-sectional	New Zealand	Examine the relationship between accelerometer derived PA in pre-schoolers and their parents.	Age, parent PA, BMI, waist circumference, attend an outdoor play ground, maternal BMI, maternal waist circumference, paternal BMI, paternal waist circumference, TV restrictions, encouragement, and being	Regression.	78 children 4-5 year olds, 62 mothers, 20 fathers. 23% overweight, New Zealand European 81%, Maori 6%, Chinese 4%.	Accelerometer Uniaxial, Actical.	6.5-7 days.	Validity cited, reliability not reported.	PA rates - Children 5.70 (1.27 - 17.64); Mothers - 3.19 (0.63 - 22.19); Fathers 3.00 (0.35 - 22.4).	

				physically active with child.							
Pate et al. (2013)[84]	Cross-sectional	USA	Determine PA levels of preschool children following the transition from indoor to outdoor settings.	Sex, BMI, and outdoor play.	Linear regression models, growth analysis.	102 children, mean age 4.2 years (SD0.7), BMI 17.5 (SD4.4), 58.8% African American, 37.3% European, 36.6% BMI < 85th% percentile.	Direct observation - outdoor setting, (OSCRAC-P).	30 minute observation session with each child observed for 10-12 sessions across 10 days.	Validity cited, reliability = 0.82.	Outdoor mean activity = girls = 2.5 (SD 0.5), boys 2.7 (SD 0.5), scale from 1 to 7, 1 sedentary and 7 most active.	
Pate et al. (2008)[85]	Cross-sectional	USA	Describe physical activity levels of children attending preschools and describe demographic correlates of physical activity in pre-schoolers.	Sex, BMI, ethnicity, age, preschool type.	ANOVA, regression.	438 children, 59% African American, 50% boys, 4.2 (SD = 0.7) years, 41% 3 years old, 59% 4-5 years old.	Direct observation.	Five second observations - 25 seconds record. 30 minute sessions, each child measured 10 - 12 times.	Reliability assessed during 12% of the total observations Inter-observer = Kappa = 0.82 (0-80-0-95).	MVPA = 3.4% (SD 1.9); TPA = 13.9% (SD 6.3).	Child care setting.
Pate et al. (2004)[86]	Cross-sectional	USA	Describe the physical activity levels of preschool children, identify demographic variables and determine variation among preschools.	Sex, preschool attended, ethnicity, age, parent education, and sex.	ANOVA, linear regression, 2-step regression.	247 children, 115 boys, 132 girls, 3-5 years, 65% black, BMI = 16.1 (SD 1.8).	Accelerometer uniaxial, 7164 Actigraph.	4.4 hour/day for 6.6 days.	Validity cited, reliability not reported.	MVPA = 7.7 (SD 3.11) min/hr.; VPA 1.9 (SD 1.1) min/hr.	Child care setting.

Penpraze et al. (2006)[87]	Cross-sectional	Scotland	Investigate the number of days and hours of monitoring required to obtain represented measures of PA of younger children.	Sex, weekday vs. weekend.	ANOVA.	76 children (40 boys, 36 girls) sub sample of a larger study, mean age 5.6 years (SD 0.4).	Accelerometer uniaxial, Actigraph.	Seven days.	Validity cited, reliability not reported.	TPA (CPM) boys = 870 (SD 187), girls 771 (SD 161).	SPARKLE STUDY.
Pfeiffer et al. (2009)[88]	Cross-sectional	USA	Determine correlates of physical activity in a large diverse sample of preschool children using accelerometer as a measure of PA.	Ethnicity, miles to park, adults VPA, BMI z score, parent's perceived child athleticism competence, physical activity equipment at home, family support, park safety, attend a park, and family support.	T-tests, ANOVA's, linear mixed models (regression).	331 children, 51.4% African-American - 40.2% white, mean age 4.3 years (SD 0.6).	Accelerometer uniaxial.	Eight-10 days.	Validity cited as a measure.	MVPA = 7.6 (SD 2.1), TPA = 27.2 (SD 3.9).	
Poest et al. (1989)[89]	Cross-sectional	USA	Describe preschool physical activity.	Weather, sex, preschool, parents PA exercise, and teacher education.	Frequency distributions, Pearson's correlation coefficient, T-tests.	514 children, 269 boys, 245 girls. Nursery children = 279, childcare children = 235.	Parent and teacher proxy report.	Questions covering 1 week.	Not reported.	25.4 hours a week being active.	
Raustorp et al. (2012)[90]	Cross-sectional	USA & Sweden	Compare pre-schoolers PA in Sweden and US settings to objectively examine the differences in preschool boys and girls indoor and outdoor PA regarding	Outdoor vs. indoor, and nationality.	T-tests, Mann Whitney U tests.	50 children, 2 preschools from USA and 2 preschools from Sweden. Mean age 4.3 years (SD 5.8).	Accelerometer uniaxial, GT1M Actigraph.	Five days of activity. If 1 day was missing then the mean daily average was used.	Both cited elsewhere.	Total: TPA (CPM) outdoor = 1098; indoor = 493. USA preschools TPA (CPM): outdoor = 1114, indoor = 406; Sweden Schools TPA (CPM): outdoors = 1081; indoors = 586.	Child care setting.

			different intensity levels and sedentary behaviour.								
Saakslahti et al. (1999)[91]	Cross-sectional	Finland	Examine physical activity over 48 hours on one weekend.	Sex and movement skills.	Correlations, t-tests, Wilcoxon 2-sample test, multiple regression.	105 children, 55 boys, 50 girls, age 3-4 years, mean age 3.75 years (SD 0.6).	Parental observations, PA diary.	48 hours over one weekend from midnight Friday to midnight Sunday.	Previously reported.	Two hours 44 minutes (SD 2 hours 34 minutes).	
Schary et al. (2012)[92]	Cross-sectional	USA	Explore the link between parent style, support and preschool children's active play behaviour.	Parental support, sex, age, and parenting style.	T-test, ANOVA, multiple linear regression.	195 children, mean age 4.0 years (SD 1.9) 46.3% boys.	Parental proxy report: PAEC-Q.	Ask parents to report no. of hour's child spends in active play (running, jumping and climbing) during a normal weekday and weekend day.	Validity cited elsewhere, weekday = r 0.35; weekend = r0.33.	8.2 hours per week.	
Shen et al. (2012)[93]	Cross-sectional	USA	Investigate the PA behaviour of urban, African American children while they attend a government funded child care program (Head Start).	Sex, age, preschool, morning childcare sessions, and preschool.	ANOVA.	158 children, 80 boys, 78 girls, 3 years = 58 children, 4 years = 100 children.	Accelerometer , tri-axial accelerometer (RT-3).	2.3 hours on 3.9 days.	Both cited elsewhere. Intra-class correlation = 0.90.	3.09 min/hr. LPA; 0.89 min/hr. MVPA.	Childcare setting.

Sugiyama et al. (2012)[94]	Cross-sectional	Australia	1) Examine organised attributes of children centres associated with pre-schoolers physical activity and sedentary behaviour while in childcare 2) Examine what environmental attributes of outdoor play areas are associated with outdoor physical activity and sedentary behaviour.	Child-staff ratio, staff training, fixed play equipment, natural outdoor surface, size of play area, outside vegetation, shadow and gradient of outdoor space.	Multi-level linear regression analysis.	89 children, mean age 4.1 years (SD 0.6), 46% girls.	Accelerometer uniaxial, GT1M Actigraph.	397.5 min/day (SD 81.1) on at least 3 days.	Not reported.	MVPA in childcare = 23.3 min/day (SD 12.6); MVPA outside in childcare = 13.5 min/day (SD 10).	Childcare setting.
Sundberg et al. (2012)[95]	Cross-sectional	Sweden	Examine if children younger than 7 years with type 1 diabetes are less active than healthy children.	Season, sex, age, type 1 diabetes, and BMI.	ANOVA, mixed linear models.	Diabetes group: 12 boys, mean age 4.3 years (SD 1.6), 12 girls, mean age 4.7 years (SD 1.9); non diabetic group: 12 boys, mean age 4.9 years (SD 1.4), 14 girls, mean age 4.4 years (SD 1.8).	Actiheart - accelerometers data only.	Two periods across the year. > 120 min (>84%) per 24 hour period. Mean 12.3 days per child.	Validity cited; reliability not cited.	Reported in figures and difficult to replicate.	
Tanaka et al. (2012)[96]	Cross-sectional	Japan	Examine the potential relationship between health-related and skill-related physical fitness habitual PA in preschool childcare.	Sex and motor skills.	ANCOVA, correlation.	136 children, mean age 5.5 years (SD 0.6), 65 girls, 71 boys.	Accelerometer uniaxial, Activtracer.	Six days, 2 hours+ on 2 weekdays and 1 weekend day.	Both cited elsewhere.	LPA = 160 (SD 30); MVPA = 95 (SD 29).	Childcare setting.

Taylor et al. (2009)[97]	Longitudinal	New Zealand	1) Investigate patterns of activity and inactivity in a birth cohort of children followed from 3 to 5 years. 2) Investigate whether changes in inactivity occur overtime.	Parental PA, age, days of the week, weekday vs. weekend day, sex, season, no. of hours in childcare, birth order, no of siblings, and weight status.	Intra class correlation, coefficient models.	244 children (44% female), age 3-5 years.	Accelerometer (Actical) and parental proxy questionnaire.	266-252 minutes/day.	Validity cited, reliability 3y 0.80(4.9days); 4 y 0.79 (51. days); 5y 0.84 (6.1 days).	Reported in figures.	
Temple et al. (2009)[98]	Cross-sectional	Canada	1) Examine levels of physical activity in that setting. 2) Examine whether levels of physical activity and sedentary behaviour differ between boys and girls.	Sex.	ANOVA.	65 children (32 girls, 33 boys) 79% age 3 to 4 years.	Accelerometer uniaxial, Actical.	Seven hours (SD0.83).	Not reported.	TPA (CPM) = 104.6 (SD 31.6); MVPA = 1.76(SD0.90).	Childcare setting.
van Rossem et al. (2012)[99]	Cross-sectional	Holland	Study associations between social disadvantage and indicators of sedentary behaviour and physical activity at preschool.	Ethnicity, mothers education, single mother, financial difficulties, mother's job status, no. of days of child care, mother pre-pregnancy BMI, and breastfeeding.	Multiple logistic regression.	2337, boys 49.9%, girls 3.01 years, 67.4% Dutch, 9.5% other western, 23.1% other western.	Questionnaire - playing outside.	Survey parent recalls over 1 week.	Not reported.	Playing outside: < 36.4% 1hour/day, 1-2 hours/day 38.4%, 2-3hours/day 17%, > 3 hours/day 8.1%.	
Verbestel et al. (2011)[100]	Cross-sectional	Belgium	Explore within-day variability of objectively measured physical activity during weekday and weekends.	Age, recess, time of day, sex, and weekday vs. weekend.	ANOVA and post hoc.	213 children, mean age 4.98 years (SD 0.88).	Accelerometer uniaxial, GT1M Actigraph.	Six consecutive days.	Both cited.	586.42 CPM/day (SD 147.36).	

Worobey et al. (2005)[101]	Cross-sectional	USA	Explore whether diet, physical activity or BMI differed across two-groups of preschool age children who attended different preschool programs.	Preschool type.	Not reported.	Forty; 4-7 years of age.	Accelerometer uniaxial, 7164 Actigraph.	Not reported.	Cited for ankle. Validity between ankle and waist = r = 0.81.	Actometer-measured activity counts: 111,661 (61,235).
Zecevic et al. (2010)[102]	cross-sectional	Canada	Examine parents influence on their young children's physical activity.	Sex, age, TV/video, parental support, parental enjoyment, parental PA habit, parent age, married parents, income, education, linguistic group, and parents belief on the importance of physical activity.	Logistic regressions.	102 preschool-aged children, 54 boys, 48 girls. Mean age 3.75 years (SD 0.80). Parents age 34 years (SD 7.0).	Questionnaire - parents proxy report.	Interviewed once.	Not reported.	Not reported.
Barkley et al. (2014)[103]	Cross-sectional	USA	Assess the effect of the presence of a friend or being alone on the intensity of and amount of physical activity.	Sex and playing with a friend or being alone.	T-tests and mixed-effects models.	20 preschool children, 10 girls, mean age 5.3 years (SD 1.1).	Accelerometer Uniaxial, GT1M Actigraph.	Children participated in 2 separate 30 minute sessions. Children were able to sample each activity before the 30 minute sessions. One session children were asked to play alone (solo). The other session the children were	Not reported.	Boys CPM for solo play = 1892 (SD 1063); girls = 1522 (SD 972). boys CPM for friend play = 2478 (SD 1276), girls 2780 (SD 884).

								asked to play with a friend(s).			
Becker et al. (2014)[104]	Cross-sectional	USA	1) Examine whether children's level of active play is related to self-regulatory skills. 2) Examine the direct connection between level of active play and academic achievement. 3) Examine whether self-regulation mediates relations between active play and academic achievement.	Emergent literacy achievement, Self-regulation (Heads-toes-knees-shoulders task), Math achievement Sex and age.	T-tests and bivariate correlates.	51 children preschool children, 22 girls, 29 boys. Mean age 4.8 years.	Accelerometer Uniaxial, GT1M Actigraph.	Correlates were measured in phase 1.2 months later active play (MVPA) was measured during one outdoor play session.	Not reported.	MVPA (Active play): 8.17 minutes (SD 4.30).	
Brasholt et al. (2013)[105]	Cross-sectional	Denmark	Examine levels and patterns in preschool children's physical activity and the effects of gender and BMI on activity.	Weekday vs. weekend; season, BMI, age, and sex.	Regression, T-tests and chi-square comparison tests.	411 children recruited. 253 children provided enough accelerometer data. Mean age 5.2 years (SD 0.7). 126 were boys (50%).	Uni-axial accelerometer, Actical.	Monitor placed on the ankle for 4 weeks. The monitor was asked not to be taken off for the 4 weeks.	Intra-monitor reliability 0.78 (95% confidence interval: 0.68-0.85).	Total group = 877±233 counts/min. Boys = 942±241 count/min; girls = 814±206 counts/min.	Analysis was adjusted for child being asthmatic or not.

Cespedes et al. (2013)[106]	Cross-sectional. RCT, but only used baseline for analysis.	USA	Examine differences in obesity-related behaviours between native born parents and immigrant born parents.	Place of birth of parent (immigrant vs. non-immigrant).	Bivariate comparison tests and regression models.	57 children with US born parents. 28(49.1%) girls, mean age 4.04 years. 64 children with parents who were not born in the US. 36 (56.3%) girls and mean age 3.92 years.	Parental questionnaire (Active play).	One question, baseline of an RCT.	Not reported.	Native born parent group took part in 1.4 (SD 0.3) hours of active play a day. Non native born parents group took part in 1.2 (SD 0.4) hours a day.	Active play was not defined as MVPA within the paper, so the Active play will be reported as total physical activity.
Driessen et al. (2013)[107]	Cross-sectional	Netherlands	Examine the link between physical activity and functional constipation.	Functional constipation.	Univariate and multivariate.	347 children, 182 boys (52%), mean age 3.34 years.	Uniaxial accelerometer. Actigraph.	One weekday, 1weekend.	Not reported.	73 ± 23 minutes spent in TPA.	Generation R study.
Edwards et al. (2013)[108]	Cross-sectional	USA	Determine the extent of PA tracking between ages 3 and 7.	Age.	MANCOVA, correlations.	234 children. 109 (85%) girls and 199 White.	Tri-axial accelerometer, RT3.	Three days the monitor was worn, 2 weekdays and 1 weekend day.	Not reported.	**Age 3:** TPA per day(CPM):443,000±114,000 MVPA per day: 85±38 LPA per day:380±45 **Age 4:** TPA per day(CPM):461,000±114,000 MVPA per day:90±37 LPA per day:382±42 **Age 5:** TPA per day(CPM):473,000 MVPA per day:94±37 LPA per day:381±42.	

Grzywacz et al. (2014)[109]	Cross-sectional	USA	Describe time spent being sedentary and MVPA by children in Latino farmworker families; and delineate sources of variation in sedentary MVPA.	Sex, mother employment status, farmworker status, attends government program, season, BMI, street traffic make it difficult to walk, dogs allowed to run loose, play equipment/toys, house has an enclosed play space, parental limits on screen time, child taken to play spaces and concern about child's level of activity.	Regression.	248 children from Latino farmworker households. 131 children are 2 year olds, 117 children are 3 year olds. 119 boys, 129 girls.	Uniaxial Accelerometer , Actical.	Eight hours of activity on 5 days with at least 1 on a weekend day.	Not reported.	Median average of 6 minutes of MVPA per day.	
Hesketh et al. (2014)[110]	Cross-sectional	England-UK	1) Investigate the association between objectively measured maternal and preschool children's PA. 2) Determine how the association of mothers PA and preschooler's differ by demographic and temporal factors.	Mothers PA.	Regression.	554 children and mothers (284 girls (51.3%), mean age 4.1 years (SD 0.1). Mean age of mothers 35.2 (SD 3.6).	Actiheart, only acclererometr y was used.	Actiheart was worn for 7 days, including sleep and bathing.	Not reported.	Average daily CPM = 130 (SD 45.8). Average daily LPA = 496.1 (SD 88.1). Average MVPA = 68.8 (SD 41.0).	Results include LPA and MVPA separately. Due to LPA and MVPA both showing the correlate direction, results were added together to create TPA.

										Southampton Womens Survey.
Hesketh et al. (2014)[111]	Cross-sectional	England-UK	Determine how children's differing intensities of activity change throughout the day and how temporal and demographic factors influence this activity.	Sex, BMI, fulltime child care, age when mother left education, time of the week (weekend vs. weekday), and season.	Regression.	593 children. 300 girls (51%), mean age 4.1 years (SD 0.1), 17% non-white.	Actiheart, only acclererometry was used.	Actiheart was worn for 7 days, including sleep and bathing.	Not reported.	TPA daily = 568.5(SD 72.2). LPA daily = 498.9 (SD 65.8) MVPA daily = 69.6 (30.7).	Southampton Womens Survey. Correlates are explored further by time of the day. Results are included for full totals. The difference of correlates by the segmented day is discussed in the discussion.
Hnatiuk et al. (2013)[112]	Prospective	Australia	Examine early childhood predictors of toddler's physical activity across domains of maternal beliefs and behaviours and the home environment.	**Correlates at 4months predicting 19 month TPA(Light-to-moderate-vigorous PA).** Maternal PA knowledge, maternal PA views, Maternal PA optimism, PA self-efficacy, maternal future	Regression.	206 children, 53.4% male; time one mean age, 3.5 months; time two mean age 8.8 months; time three mean age 18.7 months.	Uniaxial accelerometer, GT1M Actigraph.	Accelerometer was worn for seven days at the third time point (19 months). Monitor was taken off for bathing and sleeping.	Not reported.	TPA(LVPA) = 233.5 (SD 41.0).	Melbourne InFANT program.

expectations, maternal floor concerns, maternal TV knowledge, maternal TV use, maternal TV self-efficacy, maternal PA, maternal screen time, time spent playing games with adults, time spent being active with mum, time spent having tummy time, time spent on the floor, time spent with other babies of similar age, time spent with older toddlers or children, time spent outside, PA equipment in the home, and TVs in home.

Correlates at 9months predicting 19 month TPA(Light-to-moderate-vigorous PA). Maternal PA optimism, PA self-efficacy, maternal future expectations, maternal TV use, maternal TV self-

				efficacy, maternal PA, maternal screen time, time spent playing games with adults, time spent being active with mum, time spent having tummy time, time spent on the floor, time spent with other babies of similar age, time spent with older toddlers or children, time spent outside, PA equipment in the home, and TVs in home.						
Iivonen et al. (2013)[113]	Cross-sectional	Finland	Examine the relationship between objectively measured PA and outcomes of balance, locomotor and manipulative skills in 4 year old preschool children.	Sex, BMI, motor skills total score, static balance, dynamic balance, standing broad jump, sliding and galloping, kicking ball at target, throwing and catching combination, and throwing at target.	Regressions and Mann-Whitney tests.	37 children, 17 boys, mean age 4.2 years (SD 0.3) and 20 girls, mean age 4.0 years (SD 0.3).	Tri-axial accelerometer, only the vertical plan was used, so uni-axial accelerometer, GT3X Actigraph.	Five consecutive days.	Not reported.	TPA(CPM) 680.20(SD 173.78), LPA 38.82(7.21) mins per day, MVPA 60.64(SD 19.09), TPA(LVPA) 99.46(SD 25.14).

Laukkanen et al. (2014)[114]	Cross-sectional	Finland	Examine the relationship between habitual PA and gross motor skills in primary and preschool children.	Sex and gross motor skills.	T-tests and Correlations.	Preschool children only for this review. 53 preschool children, 28 preschool girls (mean age 5.95 years, SD 0.47), 25 preschool boys (mean age 5.92 years, SD 0.45).	Tri-axial accelerometer, X6-1a.	No protocol was stated for the length of time participants were asked to wear the accelerometer. 5.47 days was the average length children wore monitors and only a minimum of 500 minutes on at least 3 days with two weekdays and 1 weekend days.	Not reported.	Girls LPA = 4.65 (SD 1.05) min per day. MPA = 2.74 (SD 0.82) min per day. VPA = 2.44 (SD 1.18) min per day. Boys LPA = 5.73 (SD 1.33) min per day. MPA = 3.41 (SD 1.33) min per day. VPA = 3.05 (SD 1.93) min per day.	More specific motor skills were tested, however an overall gross motor skill score was examined with PA variables, so only overall gross motor skills were included in results.
O'Connor et al. (2014)[115]	Cross-sectional	USA	1) Develop a multi-dimensional self-report measure of pre-schoolers PA parenting practices 2) Examine the psychometric properties of the report among a Latino sample.	Parental Practices; encouragement of PA, lack of money to participate in sports clubs, outdoor toys available, safety concerns, promote inactivity, promote screen time, and psychological control.	Correlations.	94 children for accelerometer sub sample. Mean age 4.4 years (SD 0.8), 47 boys (56%) and 47 girls (44%).	Tri-axial accelerometer, only the vertical plan was used, so uni-axial accelerometer. GT3X Actigraph.	The accelerometer was worn for 7 days.	Not reported.	LPA 247(SD 36.6) mins per day. MVPA 83.4(SD 38.3) mins per day, CPM (TPA) 611.8(SD230.5).	
O'Dwyer et al. (2013)[116]	Intervention	England-UK	To investigate the effect of curricular active play intervention on PA levels.	Sex, hours in school, BMI, wear time, parents education, and ethnicity.	T-tests and multi-level models.	Total of 156 children in the Intervention group, age 4.7 (SD 0.5) years. Control group man age 4.5 years (SD 0.6).	Uniaxial accelerometer, GT1M Actigraph.	Worn for seven consecutive days.	Not reported.	Refer to study for full levels of PA. Levels are segregated by time points of the intervention and gender.	This study although an interventio n was included due to the non-effect

											of the intervention, and the multi-level model analysis which explored correlates of the group as a whole and not segregated by intervention group.
Olesen et al. (2013)[117]	Cross-sectional	Denmark	Investigate multiple potential correlates expected to be associated with preschool children's MVPA during preschool attendance.	Sex, age, BMI, motor coordination, ethnicity, born preterm, supervised trips, pre-schooler educational leader PA enjoyment, pre-schooler educational leader PA education, pre-schooler educational leader meets PA guidelines(>30min MVPA daily), staff PA enjoyment, staff PA education, staff MVPA levels, staff sex, staff young assistants, staff initiate	ICC, Multi level mixed modelling.	Data for 426 children (49.5% boys) mean age 5.8 years (SD 0.3) from 42 pre-schools had eligible data for final analysis.	Uni-axial and tri-axial accelerometers were used. Only the vertical plane function was applied, GT1M and GT3X Actigraph.	Four weeks in order to capture a minimum of 3 hours of wear time during 3 days of attending preschool. Only time during preschool was taken into account.	Not reported.	15% (SD 5.0) of preschool time was spent in MVPA for boys and 12.2% (SD 3.9) for girls.	The sum scores of natural environment, fixed toys and portable toys were only included in univariate results. For multi-level model results the specific variables are stated.

				activities, location of preschool building (N sides around the building is accessible to playground), open space, natural environment, portable toys, fixed toys, PA rooms, and access to computer.							
Ostbye et al. (2013)[118]	Intervention RCT, supplement cross-sectional study.	USA	Examine the role of the home physical activity and food environment on corresponding outcomes in young children and assess maternal education/work status as a moderator.	Age, sex, ethnicity, BMI, mother education, accessible to PA equipment, role modelling of PA, and parental policy promoting PA.	Bivariate correlations and Linear regression models.	208 children, 56% male, 55% under the age of 5, 85% White ethnicity.	Uniaxial Accelerometer , Actical.	Worn for 7 days and only taken off for bathing and sleeping. 6 hours on 3 days, 1 weekend day and 2 weekdays.	Not Reported.	17 minutes of MVPA per day.	Cross sectional sub study of a RCT.
Rice et al. (2014)[119]	Cross-sectional	USA	1) Objectively measure PA characteristics of a large and age diverse sample of children attending family day care. 2) Examine the influence of age, sex, and weight status on PA participation.	Age, BMI, and sex.	ANOVA's.	47 family day care homes. Final sample of 114 children, 52.6% boys. Mean age 3.7 years (SD 1.1).	Uniaxial Accelerometer , GT1M Actigraph.	Worn during day care. Inclusion criteria of 2 days with >75% of attendance time.	Acceleromete r intraclass reliability was 0.73-0.84.	MVPA = 5.8(SD 3.2) min/hour. TPA (LVPA) = 10.4(SD 4.4) min/hour.	

Tanaka et al. (2013)[120]	Cross-sectional	Japan	Examine the relationship between weight status and habitual physical activity in pre-school children.	Sex and weight status.	ANCOVA.	Final sample was 425 children (202 girls, 223 boys). Mean age 5.8 years (SD 0.6).	Triaxial Accelerometer , all three planes of movement were applied, Activ Tarcer.	Worn for 6 days, 4 weekdays and 2 weekend days.	Not reported.	For all groups; LPA = 157 min per day (SD 0.6). MVPA = 101 min (SD 30). Physical activity level (PAL) energy expenditure minus base metabolic rate, PAL = 1.54(SD 0.08).
Taylor et al. (2013)[121]	Prospective	New Zealand	Examine the changes in PA both overall and by categories of intensity of activity that occur in boys and girls from preschool (age 3 years) to two years after school.	Sex, age, weekday vs. weekend, rainfall, and cold weather.	Regression.	242 children (105 girls, 137 boys) had accelerometer data available for 3 years to 7 years. Only 3 to 5.5 years were inputted in the review.	Uniaxial accelerometer, Actical.	Worn for 24 hours and sleep time was subtracted by researcher. 3 hours on 5 days was the wear time criteria.	Not reported.	Girls Counts per minute (TPA) 3y:773 (SD 264) 4y: 522 (SD 220) 5y: 506 (SD 212) 5.5y: 382 (SD 128). Boys Counts per minute (TPA) 3y:813 (SD 249) 4y: 532 (SD 200) 5y: 542 (SD 244) 5.5y: 444 (SD 165).
Vale et al. (2014)[122]	Cross-sectional	Portugal	1) Objectively assess preschool children's PA patterns and compliance with guidelines of TPA and MVPA 2) Examine differences to parent's education.	Sex, weekday vs. weekend, and parental education.	T-test, ANCOVA, regression	509 healthy preschool children, 48.5% girls, mean age 5.2 years (SD 0.8).	Uniaxial accelerometer, GT1M Actigraph.	The monitor was worn for 7 days with 10 hours on each day included for analysis.	Not reported.	TPA = 141 (SD 36.3) min per day, weekday. 124.3 (SD 40.3) min per day, weekend. MVPA = 101.6 (SD 27.9) min per day, weekday. 88.1 (SD 31.0) min per day, weekend.

Vale et al. (2013)[123]	Cross-sectional	Portugal	1) Determine compliance with current PA guidelines in Portuguese preschool children 2) Examine the association between meeting daily PA recommendations and weight status.	Sex and weight status.	T-test, chi square tests, regression.	607 children, 170 girls, 172 boys. Mean age 5.1 years (SD 0.8).	Uniaxial accelerometer, GT1M Actigraph.	The monitor was worn for 7 days with 10 hours on each day included for analysis.	Not reported.	TPA = 295 (SD 51) minutes per week. MVPA 96 (SD26) minutes per week.	
van Sluijs et al. (2013)[124]	Cross sectional	UK – England	Investigate associations between a range of personal, social and environmental factors and objectively measured LPA and MVPA in four year old children.	**Personal Level:** Sex, BMI z scores, enjoyment of PA, restless, and well-behaved **Social/cultural level:** Maternal age, maternal BMI z score, age of mother, finished education, home ownership, young siblings, older siblings, maternal PA, maternal screen use, short transportation mode, parental support (rules and restrictions) TV at meal times, bedtime, snack at TV, PA-related indoor rules, play in garden, restrict	Regression models.	487 were included in the final sample. Mean age 4.1 years (SD 0.1), 47% male.	Actiheart, only acclererometry was used.	Actiheart was worn for 7 days, including sleep and bathing. Data measured during 6am to 10pm were included for analysis.	Not reported.	LPA = 502.6 (SD 63.8) min per day. MVPA = 70.3 (SD 30.9) mins per day.	Southampton Women's Survey.

				computer use, restrict TV watching, restrict playing outside, and general barriers **Environmental level:** Environmental barriers, concern about road safety, park availability, other children to play with in the neighbourhood, and season.							
Vanderloo et al. (2013)[125]	Cross-sectional	Canada	Examine the differences in peschoolers objectively measured PA levels accumulated indoors and outdoors during childcare hours.	Outdoor vs. indoor play.	Wilcoxon signed-ranked tests.	31 preschoolers (17 boys, 14 girls) mean age 4.10 years (0.85).	Uniaxial Accelerometer , Actical.	One full day during childcare.	Not reported.	Mean wear time was 451.77 (SD 81.12). Average indoor MVPA was 0.54 (SD 0.59) min per hours, and TPA was 14.42 (SD 6.78). Average outdoor MVPA was 5.03 (SD 4.92) min per hours, and TPA was 31.68 (SD 10.83).	
Wijtzes et al. (2013)[126]	Cross-sectional	Netherland s	Describe and identify correlates of objectively measured physical activity and sedentary behaviour in 2 year old toddlers.	Sex, age, preterm birth, birth weight, infant temperament, gross motor development delay, BMI z score, TV time weekdays, TV weekend days, age of mother, BMI of mother, breastfeeding,	Linear regression models.	347 children, 182 boys (52.4%), 165 girls (47.6%), mean age 2.09 years.	Uniaxial Accelerometer , Actigraph AM-7164.	Worn for at least 1 weekday and 1 weekend day. 400 minutes minimum wear time.	Not Reported.	CPM = 41.8 (11.4) MVPA% = 0.5% (0.2).	Generation R study.

				marital status, number of siblings, smoking in households, day care attendance, educational level of mother, and weekend vs. weekdays.							
Jimenez-Pavon et al. (2013)[127]	Cross-sectional	Multi-European countries (Italy, Estonia, Cyprus, Belgium, Sweden, Germany, Hungary, Spain)	Evaluate the associations between objectively-measured PA intensities and clustered CVD risk factors in a large sample of European children aged 2 to 9 years, and to provide evidence for the development of gender-specific recommendations of PA for this young population.	Sex.	T-test.	994 (2 to 6 year old children). 524 boys, 470 girls. Mean age 4.4 (SD 0.08) years.	Uniaxial Accelerometer , GT1M Actigraph.	Monitor was worn during waking hours for 4-5days. 6 hours on 3 days (2 weekdays and 1 weekend day) was the minimum wear time to be included in analysis.	Wear time reliability was cited as 80%.	CPM = 598 (174) LPA = 395 (SD 65) MVPA = 36 (SD 20).	Health outcome paper (CVD risk) but sex differences were assessed.
Tandon et al. (2012)[128]	Cross-sectional	USA	To compare the PA and beverage characteristics of a group of licensed center-and home-based child care programs with each other and with NAP SACC guidelines.	Type of child care, presence of indoor play area, hours of daily TV exposure, educational attainment of care provider.	Chi-Square, multivariate linear regression.	168 child care providers (owners, directors) provided information upon the toddlers and preschoolers enrolled in their programme. 94 were home based, 74 centre based.	Telephone survey, questionnaire.	Length of interview.	A source was cited but no mention of validity or reliability statistics.	Toddlers: 1.6 (SD 0.8) hours a day playing outside. Preschoolers: 1.7(SD 1.2) hours per day playing outside.	

Tandon et al. (2012)[129]	Cross-sectional	USA	1) to characterize the daily outdoor play frequency of preschoolers cared for at home-based child acre settings. 2) To examine the factors associated with outdoor play for these children.	Age, sex, no. regular playmates, screen time, highest education level in the house, mothers ethnicity, employment, exercise frequency of parent, hours in child care, care providers educational attainment, perceptions of neighbourhood safety, type of care, care provider is relative, care provider is a non-relative, 3 regular playmates.	Chi-square, Ordinal logistics regression.	1900 children, mean age 4.4 (SD 0.01) years, 48% girls.	Survey, questionnaire.	Length of questionnaire.	A source was cited, which stated "significant" correlation with accelerometry, however, no mention of statistics.	Play outside once or more a week = 50% (n=950) children. Play outside few times a week = 35% (n=665) children. Go outside to play a few times a month or rarely at all = 15% (n=285).	Sample part of a the ECLS-B longitudinal study.
Vanderloo et al. (2014)[130]	Cross-sectional	Canada	To measure the objective PA levels of preschoolers in childcare was well as assessing which attributes within the centre-based child care environment influenced PA.	Variables derived from the environment and policy assessment observation (EPAO) Active opportunities, Sedentary environment, Portable play equipment, Fixed play equipment, Staff behaviors, PA training and education.	Multiple regression analysis.	31 preschoolers (mean n=4.10, SD=0.85), 17 were boys.	Actical Accelerometer	Accelerometer was worn for 1 day during child care.	A source cited "accepted" validity and reliability.	TPA = 132.60 min during child care. MVPA = 11.45 min during a child care.	

Appendix 3.4. –Key for Appendices: 3.5-3.11

Study number and first author, **BOLD** refers to high quality studies. Determinant studies *(D)*.

1	Sallis, et al.	48	Cliff, et al.	95	Sundberg, et al.
2	Adams, et al.	49	Cox, et al.	96	Tanaka, et al.
3	Anderson, et al.	50	Dowda, et al.	**97**	**Taylor, et al.** *(D)*
4	Yamamoto, et al.	51	Eriksson, et al.	98	Temple, et al.
5	Williams, et al.	52	España-Romero, et al.	99	van Rossem, et al.
6	Tanaka, et al.	**53**	**Finn, et al.**	100	Verbestel, et al.
7	Vorwerg, et al.	54	Firrincieli, et al.	101	Worobey, et al.
8	Vasquez, et al.	55	Fisher, et al.	102	Zecevic, et al.
9	Vale, et al.	**56**	**Gagne, et al.**	103	Barkley, et al.
10	Vale, et al.	57	Grontved, et al.	104	Becker, et al.
11	Spurrier, et al.	58	Gubbels, et al.	105	Brasholt, et al.
12	Trost, et al.	59	Heelan, et al.	106	Cespedes, et al.
13	Hinkley, et al.	60	Iannotti, et al. *(D)*	107	Driessen, et al.
14	Hnatiuk, et al.	61	Jago, et al.	108	Edwards, et al.
15	Jackson, et al. *(D)*	62	Janz, et al.	109	Grzywacz, et al.
16	Kimbro, et al.	63	Janz, et al.	110	Hesketh, et al.
17	Sigmund, et al.	64	Kambas, et al.	111	Hesketh, et al.
18	Smith, et al.	65	Kelly, et al.]	112	Hnatiuk, et al. *(D)*
19	**Hinkley, et al.**	66	Klesges, et al.	113	Iivonen, et al.
20	Gunter, et al.	67	Kuepper-Nybelen, et al.	114	Laukkanen, et al.
21	Blaes, et al.	68	LaRowe, et al.	115	O'Connor, et al.
22	Cardon, et al.	69	Loprinzi, et al.	116	O'Dwyer, et al. *(D)*
23	Brown, et al.	70	Loprinzi, et al.	117	Olesen, et al.
24	Collings, et al.	71	Loprinzi, et al.	118	Ostbye, et al.
25	Dowda, et al.	72	Louie, et al.	119	Rice, et al.
26	Dwyer, et al.	73	Marino, et al.	120	Tanaka, et al.
27	Sallis, et al.	74	McKee, et al.	121	Taylor, et al. *(D)*
28	Benham-Deal	75	McKee, et al.	122	Vale, et al.
29	Gubbels, et al.	76	Metallinos-Katsaras, et al.	123	Vale, et al.
30	Grigsby-Toussaint, et al.	77	Mickle, et al.	124	van Sluijs, et al.
31	Fernald, et al. *(D)*	78	Montgomery, et al.	125	Vanderloo, et al.
32	Baranowski, et al. *(D)*	79	Moore, et al.	126	Wijtzes, et al.
33	**Beets, et al.**	**80**	**Niederer, et al.**	127	Jimenez-Pavon, et al.
34	Bellows, et al.	81	O'Dwyer, et al.	128	Tandon, et al.
35	Boldemann, et al.	82	O'Dwyer, et al.	129	Tandon, et al.
36	Bower, et al.	83	Oliver, et al.	130	Vanderloo, et al.
37	Brown, et al.	84	Pate, et al.		
38	Burdette, et al.	85	Pate, et al.		
39	Burdette, et al.	86	Pate, et al.		
40	**Burgi, et al.** *(D)*	87	Penpraze, et al.		
41	**Bürgi, et al.**	88	Pfeiffer, et al.		
42	Buss, et al.	89	Poest, et al.		
43	Cardon, et al.	90	Raustorp, et al.		
44	Caroli, et al.	91	Saakslahti, et al.		
45	Chuang, et al.	92	Schary, et al.		
46	Lawrence, et al.	93	Shen, et al.		
47	**Davies, et al.**	94	Sugiyama, et al.		

Appendix 3.5. – Correlates of Total Physical Activity: Full Table

	Related to physical activity		Unrelated to physical activity	Summary Code[a]		Additional coding for high quality studies[e]
	Positive Association	**Negative Association**	**No Association**			
Variables	**Reference no.**	**Reference no.**	**Reference no.**	**n/N[b] for row (%)[c]**	**Association[d]**	
DEMOGRAPHIC AND BIOLOGICAL VARIABLES						
Age	18f(meeting guidelines), 46, 54, **56**f, 57f, 58f(outdoor), 72(PA class), 83g, 93, 95, **97**, 100, 108, 119(childcare-normal weight)	**13**f, 15h, 19, 102f, 121	15i, 16f(model1), 26, 32, 43, 46, 47, 48, 65, 69f, 71f, 73(outside PA @ home), 78f, 85f, 88, 105, 113g(LVPA), 119(childcare-ow/ob), 126f, 129f(frequency play outside)	14/39(36%)	**?**	
Sex (male)	1, 6, 9, 10, 13, 15, 17(activity EE), 18f(meeting PA guidelines), **19**, 21, 22 (recess), 30(outdoor PA), 32, **33**f, 35g, 39, 42, 53g, 54, **56**f, 57f, 62, 65, 72(PA class), 74, 78f, **80**, 84(outdoor PA), 87, 88f, 89, 91, 93, 95, **97**f, 102g, 103,105, 109, 119(child care), 122, 123, 127		2, 3(no. times playing outside), 7, 8(obese children), 14, 16f(model1) 26, 31g, 42(3years), 48, 58f, 61, 64, 66f, 69f, 70(active play), 71f(home PA), 73(outside PA @ home), 73(outside PA @ preschool), 75, 76, 77,81(LPA+MVPA), 83, 85f, 92, 96, 98, 100, 114, 116g(LPA+MVPA), 121, 124f(LPA+MVPA), 126f, 129f(frequency play outside)	42/77(55%)	?	6/6(100%) ++
Ethnicity (White)	1g, 67(playing sport/outside), 73(outside PA @ home), 85f, 99(model1-playing outside), 99(model2-playing outside)	16f(model1)	3hi(no. times playing outside), 30(outdoor PA), 32, **33**f, 45f(African-American vs. Hispanic), 61, 65, 73(outside PA @ preschool), 116g(LPA+MVPA), 129g(frequency play outside - mothers ethnicity)	6/17(335%)	**?**	
Socio-economic status			1f, 15, 16f(model2), 31g, **33**f, 48, 65	0/7(0%)	**0**	
Parents education		18fk(meeting PA guidelines), **33**f, 73k(outside PA @ home), 122(weekday)	14, 16fk(model1), 30(outdoor PA), **41**, 70(active play), 86(LPA+MVPA), 99k(playing outside), 102f, 111fk(LPA+MVPA), 116f(LPA+MVPA), 122(weekend days), 124(LPA+MVPA), 126k, 129g(frequency play outside)	4/18(22%)	**0**	
Household income		18f(meeting PA guidelines)	16f(model1), 102	1/3(33%)		
Fat free-mass			59	0/2(0%)		
Preterm birth		53g, 53g(childcare PA)	126	2/2(100%)		

Birth weight	88		126f	1/1(100%)		
Adiposity		47, 51h, 83	1f, **40**, 51i, 59	3/8(38%)	**0**	
Body Mass Index (BMI)	12h, **33**f, 66f, 85, 88f	**33**f(underweight), **33**f(overweight), 46(low weight-6months), 83, 119(childcare-4-5years), 120(thinness)	3hi(no. times playing outside), 12i, 31g, 46(low weight-12months), 46(low weight-18months), 48, 49, 53, 59, 65, 68, 73(outside PA @ home), 73(outside PA @ preschool), 76, **80**, 82i(LPA+MVPA), 84(outdoor PA), 95, **97**f, 105, 111f(LPA+MVPA), 114f(LVPA), 116f(LPA+MVPA), 119(childcare), 123, 124f(LPA+MVPA), 126	6/37(14%)	0	2/5(40%) **?**
Breastfed			99(playing outside), 126f	0/1(0%)		
Smoking during pregnancy			99(playing outside)	0/1(0%)		
Mother's pre-pregnancy BMI			99(playing outside)	0/1(0%)		
Nationality	44(playing outside), 46, 90			3/3(100%)		
Aerobic fitness	40			1/1(100%)		
Gross Motor-Skill Performance	**33**f, **40**, 48h(object control scores), 54, 55, 64, 113f(total score), 113f(throwing & catching), 114h	9	48h(locomotor score), 48h(gross motor quotient), 48i(gross motor quotient), 48i(object control), 48i(locomotor score), 113f(LVPA(static balance)), 113f(LVPA(dynamic balance)), 113f(LVPA(sliding & galloping)), 113f(LVPA(standing broad jump)), 113f(LVPA(kick ball at target)), 113f(LVPA(throwing at target)), 114i, 126f	9/23(37%)	**0**	
Linguistic/language group			102f	0/1(0%)		
Physical Health		77h(Plantar pressures), 95(Type1 Diabetes), 107g(4y; functional constipation),	16f(model1;general health), 31g(stunting Status), 46(ill), 54 (history of wheezing), 77i(Plantar pressures), 91(history of wheezing), 107g(3y; functional constipation)	3/7(42%)	**?**	
Physical disorder scale	16fk(model4)			1/1(100%)		
Parents psychological wellbeing			16fk(model1)	0/1(0%)		
High maternal depressive symptoms		31g(@age15months)	31g(@age4-6years)	1/2(50%)		
Education mothers partner			126	0/1(0%)		
Immigrant background (native born parent)		106g(active play)	41(TPA), 41(time play outdoors)	1/3(33%)		
Family structure			16f(model2-no of residents in home), 16fk(model1-parents living together), 126, 16fk(model1-single parent family), 73(outside PA	0/8(0%)	**0**	

			@ home-single parent family), 99k(playing outside-single parent family), 13fi(parents martial status), 126f(parents marital status)		
Siblings(no. and order)	13fi(no.), 126g(no.)		4fhi(model4;no), **33**f, **97(no.),** 124f(LPA+MVPA; younger), 16f(model1;older), **97**(older)	2/8(25%)	**0**
Parents age			16fk(model1), 31gk, **33**fj, 88, 102, 124f(LPA+MVPA), 126, 16fk(model1-single parent family), 73(outside PA @ home-single parent family), 99k(playing outside-single parent family), 13fi(parents martial status), 126f(parents marital status)	0/7(0%)	**0**
Family financial difficulties			99(playing outside)	0/1(0%)	
Parents Body Mass Index		16fk(model1)(overweight), 53j, 66f	16fk(model1)(obese),30f(outdoor PA), 31gk, 53k(TPA), 53(childcare PA), 83, 88, 124fk(LPA+MVPA), 126f	3/12(25%)	**0**
Parents waist circumference			83j, 83k	0/2(0%)	
PSYCHOLOGICAL, COGNITIVE AND EMOTIONAL VARIABLES					
Active by themselves	**13**fh(weekend days)		13fh(weekdays)	1/2(50%)	
Personality			42	0/1(0%)	
IQ			42	0/1(0%)	
Child is more likely to play inside/draw/do crafts than be active?		13fi		1/1(100%)	
Child constraints		13fi(weekend days)	13fi(weekdays)	1/2(50%)	
Enjoyment of PA			124f(LPA+MVPA	0/1(0%)	
Restless			124f(LPA+MVPA)	0/1(0%)	
Well behaved			124f(LPA+MVPA)	0/1(0%)	
Infant temperament			126	0/1(0%)	
Internalizing behaviours (withdrawal behaviours)			31g	0/1(0%)	
Externalizing behaviours			31g	0/1(0%)	
BEHAVIORAL VARIABLES					
Prompts/request from child	1f, 58f(indoor), 58f(outdoor)			3/3(100%)	
Participation in organized sports/activities			1f, 11, 53(childcare PA)	0/3(0%)	

TV Viewing		13fh(weekdays), 31f, **33**f, 39, 61, 102f	1f, 7, 13fh(weekend days), 37, 49, 61, 70(active play), 126, 128f(outdoor play,childcare), 129g(frequency play outside)	7/17(41%)	**?**	
Objective sedentary behaviour		78f				
Quiet activities (in preschool)			7	0/1(0%)		
Bedtime			124fk(LPA+MVPA)	0/1(0%)		
Daily Sleep	**13**fh(weekdays)		13fh(weekend days)	1/2(50%)		
SOCIAL AND CULTURAL VARIABLES						
Parental PA/familial interaction	1, 11,11k 13fhk, **33**fj, 58f, 66f, 69f, 75, 79, 83g,88i, 89, **97**, 102f, 110fk9(LPA+MVPA)	31gk	1f, 13fij, 60k, 66f, 71f(home PA), 83, 88h	10/17(58%)	?	3/4(75%) **++**
Parental Practices	1f, 13fh(no rough games), 30f(outdoor PA), 69f(monitoring of PA),	83(take to playground)	61, 66, 69f, 83, 69f(style of parenting), 92f(model3), 69f(pattern of parenting), 124fk(Snack@TV), 124fk(PA indoor games), 124fk(play in garden), 124fk(restrict computer), 124fk(restrict TV), 124fk(restrict outside play), 126(smoking in home)	4/19(21%)	0	
Parents perceptions and beliefs	18f(meeting PA guidelines-self efficacy), 33f , 71f(home PA; PA competence perception), 88(competence perception), 102f(father PA enjoyment)		16f(model2; fear play outside), 18(organised PA-self efficacy), 18f(non-organised PA-self efficacy), 102f(PA importance),	5/9(21%)	0	
Parent(s) work status	33fk(full-time), 41k(part-time)	13fik(part-time-weekday), 13fik(fulltime-weekend), 16fk(model1)(part-time), 16fk(model1) (fulltime)	13fik(part-time-weekend), 13fik(fulltime-weekday), 33fj(full-time), **33**fj(part-time), **33**fk(part-time), 99k(playing outside), 126k, 126(partner), 129g(frequency play outside)	4/15(27%)	?	
Parental barriers		13fh(weekdays),18f(meeting PA guidelines), 18(organised PA), 115	13fh (weekends),18f(non-organised PA), 124fk(LPA+MVPA)	4/7(57%)	**?**	
Parental support	13fi(weekend days), 30(outdoor PA), 69f, 71f(home PA), 88, 92f(model1), 102		1f, 13**fi**(weekdays), 61, 66f, 83, 115(LPA+MVPA) 124fk(LPA+MVPA)	7/14(50%)	**?**	
Collective efficacy	16fk(model3)			1/1(100%)		
Frequency child sees parent being active			13fi	0/1(0%)		
Frequency child sees other adults being active			13fi	0/1(0%)		
Peers to be active with	13fh		129f(frequency of play outside)	1/1(100%)		

Same activities as siblings	13fh (weekdays)	13fh(weekend days)	1/2(50%)
Attendance to social gatherings		13f	0/1(0%)
Social gatherings that are not active in nature		13fh	0/1(0%)
Number of cars in the home		13fh, 102f	0/2(0%)
Parental work-load (high)		**41**	0/1(0%)
Dog ownership		11	0/1(0%)
Teacher's/day care worker education/training	88, 36g	**56**f, 129(frequency playing outside)	2/3(66%)
Teacher/day care worker age	**56**f		1/1(100%)
Teacher/day care worker INTENTION of engaging to get children to be active.	**56**f		1/1(100%)
No. days child is in the care of others		99(playing outside)	0/1(0%)
Democratic interventions of teachers/day care workers	**56**f		1/0(100%)
Teachers/day care workers DECRIPTIVE NORM (perceived fewer educators engage children in physical activity)	**56**f		1/1(100%)
Teachers/day care worker PAST BEHAVIOR - (engaging children to be active).		**56**f	0/1(0%)
Highest education of child care provider		128f(outdoor play)	0/1(0%)
Playing with friends vs. alone	103, 129(frequency play outside-parental childcare, n=≥3 friends), 129(frequency play outside-parental childcare, n=≥3 friends)		3/3(100%)
House ownership		124f(LPA+MVPA)	0/1(0%)
Family exercise frequency		129f(frequency play outside)	0/1(0%)
PHYSICAL ENVIRONMENTAL VARIABLES			

Time outdoors/in play spaces	1f, 7, 35i, 66, 72(PA class), 90, 125		73f(outside PA @ preschool)	+ 7/8(89%)	+
Attend nursery/kindergarten/children's centre/preschool	21	43	16fk(model1), 17, 126g	1/4(20%)	0
Nursery/kindergarten/children's centres have PA promoting policies and practices	20(childcare)			1/1(100%)	
Convenient play spaces	1f		11(presence of playground near to home), 73f(outside PA @ home-presence of playground near home)	1/3(33%)	
Family lives in public/social housing		16f(model2)		1/1(100%)	
Frequency in play spaces	1f			1/1(100%)	
Play equipment at home	88f			1/2(5%)	
Presence of playground at preschool	73f(outside PA @ preschool)			1/1(100%)	
Weather conditions	89			1/1(100%)	
Availability of toys			1f, 115(LPA+MVPA)	0/2(0%)	
Distance to park (miles)			88f	0/1(0%)	
Attend/go to a park			88	0/1(0%)	
Park safety			88	0/1(0%)	
Safe place to play	75			1/1(100%)	
Have desktop computer in home		13fh(weekend days)	13fh(weekdays)	1/2(50%)	
Season (summer)	39, 75, 95, 105, 126g	16fk(model1), 53(childcare PA)	53, 97, 124fk(LPA+MVPA)	5/10(50%)	?
Region of house (urban)	18f(meeting PA guidelines)	72(PA class)		1/2(50%)	
Region of preschool/child care centre	73(outside PA @ preschool)		57	1/2(50%)	
Region of country	**41**(TPA), **41**(time play outdoor)		73(outside PA @ home)	4/8(50%)	?
No. hours of childcare/preschool	116f		**97**	0/1(0%)	
Housing type (apartment(A),row house(RH), other housing)		16f(model2)	16f(model2)	1/2(50%)	

Weekday versus weekend (weekday)	7, 10, 34, 122	13, 38(outdoor PA), 87, 105, 121, 126	17(activity EE), 75, 97, 100, 111f(LPA+MVPA)	6/15(33%)	**?**
Days of week			**97**	0/1(0%)	
Preschool-PE classes	9			1/1(100%)	
Time at preschool (full day)			73(outside PA @ home)	0/1(0%)	
Time at preschool (half day)			73(outside PA @ home)	0/1(0%)	
Time of day (afternoon)	28, 100		32, 93	2/4(50%)	**?**
Month of PA data collected	13fi(aug-weekend days)		13fi(aug-weekdays), 13fi(sep), 13fi(oct), 13fi(nov), 13fi(dec)	1/6(17%)	**0***
No footpaths in neighbourhood		**13**fi		1/1(100%)	
Size of backyard/garden	11			1/1(100%)	
Yard near home	73f(outside PA @ home)			1/1(100%)	
No. items of outdoor play equipment	11			1/1(100%)	
Time outdoors on weekends	13fh(weekdays)		13fi	1/2(50%)	
No. visits to shopping centres per week			13fh	0/1(0%)	
Use of balls and objects (preschool outside)	23f			1/1(100%)	
Childcare physical activity promoting polices			57	0/1(0%)	
Open space outside at preschool	23f			1/1(100%)	
Childcare Fixed play equipment		130	23f	1/2(50%)	
Wheel toys outside at preschool	23f			1/1(100%)	
Playing one-to-one with peers	23f			1/1(100%)	
Playing in a group without an adult	23f			1/1(100%)	
Playing solitary at preschool	23f			1/1(100%)	
Children initiator of activities	23f			1/1(100%)	
Neighbourhood vegetation	30f(outdoor PA)			1/1(100%)	
Neighbourhood quality			**33**f	0/1(0%)	

Neighbourhood safety (perceived)	**33**f		38, 128f(frequency of play)	1/3(33%)	
Frequency of visits to active play spaces (per week)	**13**fh(weekdays)	**13**fi(weekend days)	**13**fh(weekend days), **13**fi(weekdays)	1/4(25%)	**0**
Recess (take part)	100			1/1(100%)	
Recess - no. children per m2		22(steps(p/m))		1/1(100%)	
Recess - no. supervising teachers		22i(steps(p/m))	22h(steps(p/m))	1/2(50%)	
Recess - aiming equipment			22h(steps(p/m)), 22i(steps(p/m))	0/2(0%)	
Recess - playing equipment			22h(steps(p/m)), 22i(steps(p/m))	0/2(0%)	
Recess - recess duration		22h(steps(p/m)), 22i(steps(p/m))		2/2(100%)	
Recess - ground surface type		22h(steps(p/m))	22I(steps(p/m))	1/2(50%)	
Recess - playground markings			22h(steps(p/m)), 22i(steps(p/m))	0/2(100%)	
Recess - vegetation			22h(steps(p/m)), 22i(steps(p/m))	0/2(100%)	
Recess- height differences			22h(steps(p/m)), 22i(steps(p/m))	0/2(100%)	
Recess - outdoor play time		84(20min<)		1/1(100%)	
Recess - availability of toys			22h(steps(p/m)), 22i(steps(p/m))	0/2(0%)	
Childcare-type (Centre v home)	129(outdoor play-non-relation care provider in child home)		128(outdoor play), 129(frequency play outside-non realtion care in another home), 129(outdoor play-family relation care provider)	1/4(25%)*	
Childcare-indoorplay			128f(outdoor play)	0/1(0%)	
Childcare - leisure time activities	35i			1/1(100%)	
Childcare - outdoor environment quality	35i			1/1(100%)	
Childcare - portable play environment	36g, 130			2/2(100%)	
Childcare - sedentary environment		36g(mean PA)		1/1(100%)	
Childcare – active opportunities	36g, 58f(indoors), 58f(outdoors)			3/3(100%)	
Childcare - sedentary opportunities			130	0/0(0%)	
Group size in child care - peers (large)		58g(indoors), 58(outdoors)		2/2(100%)	

Group size in child care - staff (large)		58g(indoors), 58(outdoors)		2/2(100%)	
Childcare staff behaviours			130	0/0(0%)	
Childcare indoor PA promoting space layout			56f	0/1(0%)	
Childcare PA promoting materials available	56f			1/1(100%)	
Individual preschool/childcare	53, 53(childcare PA), 57f, 89, 93, 101			6/6(100%)	+
Rain		121		1/1(100%)	
Weather (temperature)		121		1/1(100%)	
Environmental barriers			124fk(LPA+MVPA)	0/1(100%)	
Concern about safety			124fk(LPA+MVPA)	0/1(100%)	
Park availability			124fk(LPA+MVPA)	0/1(100%)	
Environment and Policy Assessment and Observation (EPAO) Total score			130	0/0(0%)	

a = summary code is an overall summary of finding for each variable

b N = number of studies that have investigated and reported on possible associations between the variable and physical activity; n = number of studies that report support for the direction of the hypothesized association.

c N = association shows the direction of the individual/summary association (+/-/?/0) – codes in **bold** are the final result for each correlate

d = additional coding for studies that scored a moderate to high quality rating (++/--/oo/?) – codes in **bold** are the final result for each correlate

e = additional coding for studies that scored a high quality rating (++/--/oo/?) – codes in **bold** are the final result for each correlate

f = reported in a multivariate analysis

g = reported in a multivariate and univariate analysis

h = association for boys only

i = association for girls only

j = paternal behaviour

k = maternal behaviour.
l = correlate at 4 months of age predicting physical activity at 19 months of age.
m = correlate at 9 months of age predicting physical activity at 19 months of age.
MPA = moderate physical activity.
VPA = vigorous physical activity.
MVPA = moderate to vigorous physical activity.
LVPA = light to vigorous physical activity.
* one study testing different months so no additional coding is awarded. N in **Bold** = High quality studies.

Appendix 3.6. – Determinants of Total Physical Activity: Full Table

	Related to physical activity		Unrelated to physical activity	Summary Code[a]	
	Positive Association	Negative Association	No Association		
Determinant	Reference no.	Reference no.	Reference no.	n/N for row (%)[b]	Association[c]
DEMOGRAPHIC AND BIOLOGICAL VARIABLES					
Age	15	**97**, 121	32	2/4(50%)	**?**
Sex (male)	32, 121		**97**f	2/3(66%)	**+**
Ethnicity (White)			32, 116g(LPA+MVPA)	0/2(0%)	**0**
Parents education			116f(LPA+MVPA)	0/1(18%)	**0**
Adiposity			**40**	0/1(0%)	**0**
Body Mass Index (BMI)			**97**f, 116f(LPA+MVPA)	0/2(0%)	**0**
Aerobic fitness			**40**	0/1(0%)	**0**
Gross Motor-Skill Performance			**40**	0/1(0%)	**0**
High maternal depressive symptoms		31g		1/1(100%)	**-**
SOCIAL AND CULTURAL VARIABLES					
Parental PA	**97j**		60k, **97**k, 112fkl(modelA), 112fkm(modelA)	1/6(20%)	**0**
Parental PA knowledge			112fkl(modelA)	0/1(0%)	**0**
Parental PA views			112fkl(modelA)	0/1(0%)	**0**
Parental PA optimism	112fkm(modelA)		112fkl(modelA), 112fkm(modelB)	1/3(33%)	**0**
Parental PA self-efficacy			112fkl(modelA), 112fkm(modelA)	0/2(0%)	**0**
Parental PA future expectations			112fkl(modelA), 112fkm(modelA)	0/2(0%)	**0**
Parental floor concerns			112fkl(modelA)	0/1(0%)	**0**
Parental TV knowledge			112fkl(modelA)	0/1(0%)	**0**
Parental TV use			112fkl(modelA), 112fkm(modelA)	0/2(0%)	**0**
Parental TV self-efficacy			112fkl(modelA), 112fkm(modelA)	0/2(0%)	**0**
Parental screen time			112fkl(modelA), 112fkm(modelA)	0/2(0%)	**0**
Time spent playing outside with adults			112fl(modelA), 112fm(modelA)	0/2(0%)	**0**

Time spent playing with parent	112fkm(modelA), 112fkm(modelB), 112fkm(modelC)		112fkl(modelA)	3/4(75%)	**+**
Tummy time			112fl(modelA), 112fm(modelA)	0/2(0%)	**0**
Time spent on the floor			112fl(modelA)	0/1(0%)	**0**
Time spent with peers of the similar age		112fm(modelA)	112fl(modelA), 112fl(modelB), 112fl(modelC), 112fm(modelB)	1/5(20%)	**0**
Time spent with older toddlers or children			112fl(modelA), 112fm(modelA)	0/2(0%)	**0**
PHYSICAL ENVIRONMENTAL VARIABLES					
Time outdoors/in play spaces			112fl(modelA), 112fm(modelA)	0/2(0%) +	**0**
Play equipment at home			112fl(modelA), 112fm(modelA)	0/2(0%)	**0**
Time of day (afternoon)			32	0/1(0%)	**0**
TV in home			112fl(modelA), 112fm(modelA)	0/2(0%)	**0**

a = summary code is an overall summary of finding for each variable

b N = number of studies that have investigated and reported on possible associations between the variable and physical activity; n = number of studies that report support for the direction of the hypothesized association.

c N = association shows the direction of the individual/summary association (+/-/?/0) – codes in **bold** are the final result for each correlate

d = additional coding for studies that scored a moderate to high quality rating (++/--/oo/?) – codes in **bold** are the final result for each correlate

e = additional coding for studies that scored a high quality rating (++/--/oo/?) – codes in **bold** are the final result for each correlate

f = reported in a multivariate analysis

g = reported in a multivariate and univariate analysis

h = association for boys only

i = association for girls only

j = paternal behaviour

k = maternal behaviour.

l = correlate at 4 months of age predicting physical activity at 19 months of age.

m = correlate at 9 months of age predicting physical activity at 19 months of age.

MPA = moderate physical activity.

VPA = vigorous physical activity.

MVPA = moderate to vigorous physical activity.

LVPA = light to vigorous physical activity.

* one study testing different months so no additional coding is awarded.

N in **Bold** = High quality studies.

Appendix 3.7. – Correlates of Moderate-to-Vigorous Physical Activity: Full Table

	Related to physical activity		Unrelated to physical activity	Summary Code[a]		Additional coding for high quality studies [e]
	Positive Association	**Negative Association**	**No Association**			
Determinant Variables	**Reference no.**	**Reference no.**	**Reference no.**	**n/N [b] for row (%)[c]**	**Association[d]**	
DEMOGRAPHIC AND BIOLOGICAL VARIABLES						
Age	57f, **80**(VPA), 88, 95, 108, 118g, 119(childcare-normal weight), 126g	4fl(model4), 48h	4fh(model4), 26(MPA+VPA), 48h(%VPA), 71, **80**, 85f, 86g, 93, 104(active play), 117(preschool), 119(childcare-ow/ob)	8/21(30%)	**?**	
Sex (male)	6, 7(VPA), 9, 10, **19**(%MPA), 21, 24(MPA), **40**, 43(MPA), 52, 53g(%VPA), 54, 57f, 62(VPA), 63(VPA), 76(VPA), 78, **80**, 86g, 88f, 95, 96, 105, 111f, 115, 117(preschool), 118g, 119(childcare), 120, 122, 123, 126g, 127	85f	14, **19**(%VPA), 24(VPA), 26(MPA+VPA) 43, 48, 62(MPA), 63(MPA), 71, 76, 77, 81, 93, 98, 104(active play), 109g, 113g, 114(VPA), 116f, 124f	33/54(61%)	+	3/4(75%) ++
Ethnicity (White)	85f(African-American)	86f(African-American, model2, VPA), 88g(African-American)	86f(African-American, model1, MPA), 117(preschool, west country), 117(preschool, others), 118g	2/7(28%)	**0**	
Socio economic status			48, 126f, 65	0/3(0%)		
Parents education (degree)	117g(preschool)	122weekdays)	4fhi(model4), 14, **41**, 86f, 111fk, 116fk, 118gk, 122(weekend), 124fk, 126k,126(partner)	1/13(8%)	**0**	
Parents age			88, 124fk, 126k	0/3(0%)		
Fat free-mass		59i	59h	1/2(50%)		
Immigrant background			4fhi(model4), **41**	0/2(0%)		
Preterm birth		53g(%VPA), 117g(preschool), 126		3/3(100%)		
Birth weight	88		126g	1/2(100%)		

Adiposity		24f(% body fat, VPA), 24f(fat free mass, VPA), 24f(trunk fatness index, VPA)	40, 24f(% body fat, MPA), 24f(fat free mass, MPA), 24f(trunk fatness index, MPA), 59h	3/8(37.5%)	**?**
Body Mass Index (BMI)	82h(MPA-weekday), 85, 88g	76(VPA), **80**(VPA), 119(childcare-4-5years), 123i	27f(MPA),48, 49, 53(%VPA), 59, 68, 76, **80**, 82h(MPA, weekend), 82h(VPA), 82i, 95, 109k, 111f, 113f, 116f, 117(preschool), 118g, 119(childcare-2-3years), 120, 123h, 124f, 126g	4/30(13%)	**0**
Parents BMI		27fj(MPA)	4fhi(model4), 27fk(MPA), 53k(%VPA), 88, 124fk, 126gk	1/6(17%)	**?**
Aerobic fitness	40			1/1(100%)	
Breastfeeding			126g	1/1(100%)	
Physical Health	4fi(model4-health status)	54 (VPA-history of wheezing), 77h (plantar pressures), 95(Type I diabetes), 107g(4years-functional constipation)	4fh(model4-health status), 77i (plantar pressures), 46(VPA-illness), 107g(3years-functonal constipation)	4/9(44%)	**?**
Gross motor-skill performance	5(4years), **40**, 48hg(object control scores), 54, 55, 96(related to fitness), 113g(total score), 113g(sliding & galloping), 113g(throwing & catching), 114h(MPA), 117g(preschool)	48ij(locomotor skills), 48i(gross motor quotient)	5(3years), 48h(locomotor score), 48h(gross motor quotient), 48i(object control), 48i(locomotor score), 113g(static balance), 113g(dynamic balance), 113g(standing broad jump), 113g(kicking ball at target), 113g(throwing at target), 114h(VPA), 114i, 126g	10/25(40%)	**?**
Skills related to physical fitness	96			1/1(100%)	
Family CVD risk		27f(MPA)		1/1(100%)	
Siblings (no. and order)	124f (older sibling), 126g		124f(younger sibling)	2/3(66%)	
PSYCHOLOGICAL, COGNITIVE AND EMOTIONAL VARIABLES					
Desire to be active	4fh(model4)		4fi(model4)	1/2(50%)	
Infant temperament			126	1/1(100%)	
Self-regulation	5(active play)			1/1(100%)	
Literacy			5(active play)	0/1(0%)	
Math achievement			5(active play)	0/1(0%)	

Enjoyment of PA			124f	0/1(0%)	
Restless			124f	0/1(0%)	
Well behaved			124f	0/1(0%)	
Type A behaviour			27f(MPA)	1/1(100%)	
BEHAVIOURAL VARIABLES					
Energy intake whilst watching TV		49(weekend days)	124f(meals), 124f(snacks)	1/1(100%)	
Surveys of obsegenic foods		49		1/1(100%)	
Surveys of fruits/veg			49	0/1(0%)	
Participation in organized sports/activities	4fh(model3)		4fi(model4), 53(%VPA)	1/3(33%)	
Sedentary behaviours: electronic, media/screen viewing (TV, computer, games)	4fh(model4)	25	49, 126	1/4(25%)	**0**
TV commercial viewing			49	0/1(0%)	
Non TV commercial viewing			49	0/1(0%)	
Bedtime			124k	0/1(0%)	
SOCIAL AND CULTURAL VARIABLES					
Parental PA/familial interaction	4fi(model4), **13**fij(MPA), 27f(MPA), 110fk		4fh(model4), **13**fik(VPA), 88, 124fk	4/8(50%)	**?**
Parents screen time			124fk	0/1(0%)	
Short transportation mode (inactive)	124fk			1/1(100%)	
Family support			88	0/1(0%)	
Parental support			71, 124fk	0/1(0%)	
Parent’s perception of their child's competence to be active	71, 88f			2/2(100%)	
Parents concern about child’s level of activity			109g	0/1(0%)	

Parent(s) work status	**41**k(fulltime), **41**k(part-time), 109kf		109k, 126k, 126(partner)	3/6(50%)	**?**
Farmworker status			109k	0/1(0%)	
Parental work-load (high)			**41**	0/1(0%)	
Teacher's/day care worker education	50(outside)		25	1/2(50%)	
Teachers PA/day care worker training	94f		25	1/2(50%)	
Teacher/day care worker PA			25	0/1(0%)	
Limits on screen time			109g	0/1(0%)	
Promote inactivity			115	0/1(0%)	
Psychological concern			115	0/1(0%)	
Home ownership (renting)			124f	0/1(0%)	
PA related indoor rules			124f	0/1(0%)	
Play in garden			124f	0/1(0%)	
Restrict computer use			124f	0/1(0%)	
Restrict TV watching			124f	0/1(0%)	
Restrict playing outside			124f	0/1(0%)	
Barriers to PA			124f	0/1(0%)	
Smoking in house hold			126	0/1(0%)	
Rain days			117g(preschool)	0/1(0%)	
Free time (childcare)		50(child care)		1/1(100%)	
Role modelling of PA			118g	0/1(0%)	
PHYSICAL ENVIRONMENTAL VARIABLES					
Attend nursery/kindergarten/children's centre/preschool	21(MPA), 111f		21(VPA), 109k, 126g	2/5(40%)	**?**
Time outdoors/in play spaces	90, 109g	50(child care)	4fhi(model4), 25, 109g	2/6(33%)	**0**
Play equipment at home	88		109g, 118g	1/3(33%)	
Distance to park (miles)		88f		1/1(100%)	

Attend/go to a park			88	0/1(0%)	
Use of space in child care for motor activities	94f			1/1(100%)	
Supervised school trips			117(preschool)	0/1(0%)	
Time using playground			117(preschool)	0/1(0%)	
Natural outdoor surface		94f		1/1(100%)	
Season	95(summer), 111f, 124f(spring)	126f(winter)	53(%VPA), 109k, 124f(autumn), 124f(summer)	3/8(38%)	**?**
Region of country	**41**		117g(preschool)	1/1(100%)	
Size of playground	25		94f, 117(preschool)	1/3(33%)	
Access from playground to preschool building (no. of accessible building sides to playground)	117f(preschool)			1/1(100%)	
Childcare outside vegetation			94f	0/1(0%)	
Gradient of outdoor space			94f	0/1(0%)	
Home has enclosed play space			109g	0/1(0%)	
Childcare SHADE in outdoor space			94f	0/1(0%)	
Size of childcare centre			94f	0/1(0%)	
Perceived environment and neighbourhood opportunities to play			4fhi(model4)	0/1(0%)	
Preschool			117g	0/1(0%)	
Weekday versus weekend (weekday)	10, 122		28, 43, 111f, 126	2/6(33%)	**?**
Time of day (afternoon)	117g(preschool)		28, 93	1/3(33%)	
Use of balls and objects (preschool outside)	23f			1/1(100%)	
Preschool-PE classes	9			1/1(100%)	
Area indoor per child	117f(preschool)			1/1(100%)	

Childcare physical activity promoting polices	25f			1/1(100%)
Open space outside at preschool	23f			1/1(100%)
Fixed equipment outside at preschool	23f, 94f	25		2/3(67%)
Wheel toys outside at preschool			23f	0/1(0%)
Playing one-to-one with peers	23f			1/1(100%)
No. field trips in childcare	50		25	1/2(50%)
No. community organised visits			25	0/1(0%)
No. children per classroom			25, 50	0/2(0%)
Playing in a group without an adult	23f			1/1(100%)
Playing solitary at preschool	23f			1/1(100%)
Children initiator of activities	23f			1/1(100%)
No. portable playground equipment	25			1/1(100%)
Childcare: Portable play environment			130	0/0(0%)
Childcare ITEMS - portable jumping equipment	29(indoor)			1/1(100%)
Childcare ITEMS - push-pull toys	29(indoor)		29(outdoor)	1/2(50%)
Childcare ITEMS - slides (portable)	29(indoor)			1/1(100%)
Childcare ITEMS - slides (Fixed)	29(indoor), 29(outdoor)			2/2(100%)

Childcare ITEMS - fixed balancing surfaces	29(indoor)		29(outdoor)	1/2(50%)
Childcare ITEMS - riding toys (portable)		29(indoor)	29(outdoor)	1/2(50%)
Childcare ITEMS - sand/water toys (portable)		29(indoor)		1/1(100%)
Childcare ITEMS - balls			29(indoor), 29(outdoor)	0/2(0%)
Childcare ITEMS - portable climbing structures			29(indoor), 29(outdoor)	0/2(0%)
Childcare ITEMS - floor play equipment			29(indoor), 29(outdoor)	0/2(0%)
Childcare ITEMS – twirling equipment			29(indoor), 29(outdoor)	0/2(0%)
Childcare ITEMS - fixed structured track	29(outdoor)		29(indoor)	1/2(50%)
Childcare ITEMS - merry-go-around			29(indoor), 29(outdoor)	0/2(0%)
Childcare ITEMS - fixed climbing structures	29(outdoor)		29(indoor)	1/2(50%)
Childcare ITEMS - see saw			29(indoor), 29(outdoor)	0/2(0%)
Childcare ITEMS - fixed tunnels	29(outdoor)		29(indoor)	1/2(50%)
Childcare ITEMS - sand box	29(outdoor)		29(indoor), 29(outdoor)	1/3(33%)
Childcare ITEMS - jumping equipment	29(outdoor)			1/1(100%)
Childcare ITEMS - swinging equipment			29(indoor), 29(outdoor)	0/2(0%)
Childcare - portable play environment	36g		117g(preschool)	1/1(100%)
Childcare - fixed play environment		36g	117g(preschool), 117f(preschool sport equipment)	1/3(33%)

Childcare - active opportunities	36g			1/1(100%)	
Childcare: Sedentary Opportunities			130	0/0(0%)	
Staff - child ratio (low level)	94f			1/1(100%)	
Preschool: PA rooms			117(preschool)	0/1(0%)	
Preschool open space			117(preschool)	0/1(0%)	
Vegetation on preschool grounds		118g(preschool)		1/1(100%)	
Preschool hilly landscape			117(preschool)	0/1(0%)	
Childcare - support from community organizations			50	0/1(0%)	
Childcare/preschool overall quality			5	0/1(0%)	
Childcare - computer use			50, 117(preschool)	0/1(0%)	
Individual preschool/childcare	53(%VPA), 57f, 86f		50	3/4(75%)	+
Street traffic makes it difficult to walk			109g	0/1(0%)	
Dogs allowed to run loose			109g	0/1(0%)	
Parental safety concerns			115	0/1(0%)	
Preschool educational leader enjoyment of PA			117(preschool)	0/1(0%)	
Preschool educational leader PA education level			117g(preschool)	0/1(0%)	
Preschool educational leader meet PA guidelines (>30MVPA min per day)			117(preschool)	0/1(0%)	
Preschool staff enjoyment of PA			117(preschool)	0/1(0%)	
Preschool staff education level			117(preschool)	0/1(0%)	

Preschool staff meet PA guidelines (>30MVPA min per day)			117(preschool)	0/1(0%)
Preschool staff sex (male)			117(preschool)	0/1(0%)
Preschool staff young assistants			117(preschool)	0/1(0%)
Preschool staff initiate PA			117(preschool)	0/1(0%)
Staff Behaviors			130	0/0(0%)
Environmental barriers			124f	0/1(0%)
Road safety concern			124f	0/1(0%)
Park availability			124f	0/1(0%)
Neighbourhood children to play with		124fh	124fi	1/2(50%)
Playing outside versus Inside	125h		125i	1/2(50%)
Environment and Policy Assessment and Observation (EPAO) Total score			130	0/0(0%)

a = summary Code is an overall summary of finding for each variable

b N = number of times reported associations between the variable and physical activity; n = number of times supporting the direction of the hypothesized association. N = total number of times variables has been investigated

c = percentage % of studies finding an association

d = association shows the direction of the individual/summary association (+/-/?/0) – codes in **bold** are the final result for each correlate

e = additional coding for studies that scored a high quality rating (++/--/oo/?) – codes in **bold** are the final result for each correlate

f = reported in a multivariate analysis

g = reported in a multivariate and univariate analysis

h = association for boys only

i = association for girls only

j = paternal behaviour

k = maternal behaviour.

MPA = moderate physical activity.

VPA = vigorous physical activity.

N in **Bold** = High quality studies

Appendix 3.8. – Determinants of Moderate-to-Vigorous Physical Activity: Full Table

	Related to physical activity		Unrelated to physical activity	Summary Code[a]	
	Positive Association	**Negative Association**	**No Association**		
Determinant Variables	**Reference no.**	**Reference no.**	**Reference no.**	**n/N[b] for row (%)[c]**	**Association [d]**
DEMOGRAPHIC AND BIOLOGICAL VARIABLES					
Sex (male)	**40**	116f		1/2(50%)	**?**
Ethnicity(white)			116f	0/1(0%)	**0**
Parents education (degree)			116fk	0/0(0%)	**0**
Adiposity			**40**	0/1(0%)	**0**
Body Mass Index (BMI)			116f	0/1(0%)	**0**
Aerobic fitness			**40**	0/1(0%)	**0**
Gross motor-skill performance			**40**	0/1(0%)	**0**
PHYSICAL ENVIRONMENTAL VARIABLES					
Hours spent at preschool			116f	0/1(0%)	**0**

a = summary Code is an overall summary of finding for each variable

b N = number of times reported associations between the variable and physical activity; n = number of times supporting the direction of the hypothesized association. N = total number of times variables has been investigated

c = percentage % of studies finding an association

d = association shows the direction of the individual/summary association (+/-/?/0) – codes in **bold** are the final result for each correlate

f = reported in a multivariate analysis

g = reported in a multivariate and univariate analysis

h = association for boys only

i = association for girls only

j = paternal behaviour

k = maternal behaviour.

MPA = moderate physical activity.

VPA = vigorous physical activity.

N in **Bold** = High quality studies

Appendix 3.9. – Correlates of Light Physical Activity: Full Table

	Related to physical activity		Unrelated to physical activity	Summary Code[a]		Additional coding for high quality studies [e]
Determinant Variables	Positive Association Reference no.	Negative Association Reference no.	No Association Reference no.	n/N[b] for row (%)[c]	Association [d]	
DEMOGRAPHIC AND BIOLOGICAL VARIABLES						
Age	108	86		1/2(50%)		
Sex (male)	21, 24, 78, 114, 127		14, 26, 81, 86, 96, 111f, 113, 120, 124f	5/14(35%)	?	
Ethnicity (White)			86	0/1(0%)		
Adiposity			24f(% body fat), 24f(fat-free mass), 24f (trunk fat mass index)	0/3(0%)		
Body Mass Index (normal weight)			68, 76, 82, 111f, 120, 124f	0/6(0%)	0	
Plantar Pressures			77	0/1(0%)		
Gross motor-skill performance	55, 114h	9	114i,	2/3(67%)		
Skills related to fitness			96,	0/1(0%)		
Functional constipation		107g(4years)	107g(3years)	1/2(50%)		
Parents education			14, 86, 111fk, 124fk	0/4(0%)	0	
Parents age			124fk	0/1(0%)		
Parents Body Mass Index			124fk	0/1(0%)		
Younger siblings			124f	0/1(0%)		
Older siblings			124f	0/1(0%)		
PSYCHOLOGICAL, COGNITIVE AND EMOTIONAL VARIABLES						
Enjoyment of PA			124f	0/1(0%)		
Restless			124f	0/1(0%)		
Well behaved			124f	0/1(0%)		
BEHAVIOURAL VARIABLES						
TV Viewing			49	0/1(0%)		
Bedtime			124f	0/1(0%)		
SOCIAL AND CULTURAL VARIABLES						
Parental PA/familial interaction	109fk, 124fk			2/2(100%)		
Cost of sports clubs as a barrier			115	1/1(100%)		
Parental safety concerns			115	0/1(0%)		

Parents promote inactivity			115	0/1(0%)
Parents promote screen time		115		1/1(100%)
Parental psychological control			115	0/1(0%)
Home ownership			124f	0/1(0%)
Parents screen use			124f	0/1(0%)
Parental support			115, 124fk	0/2(0%)
Short transportation mode			124f	0/1(0%)
TV at mealtimes			124f	0/1(0%)
Snack at TV			124f	0/1(0%)
PA-related indoor rules			124f	0/1(0%)
Play in garden			124f	0/1(0%)
Restrict computer use			124f	0/1(0%)
Restrict TV watching			124f	0/1(0%)
Restrict playing outside			124f	0/1(0%)
General PA barriers			124f	0/1(0%)
PHYSICAL ENVIRONMENTAL VARIABLES				
Time outdoors/ in play spaces			115	0/1(0%)
Attend nursery/kindergarten/children’s centre/preschool	21		111f	1/2(50%)
Season (summer)			111f, 124f	0/2(0%)
Weekday versus weekend (weekday)			111f	0/1(0%)
Availability of toys			115(outdoor toys)	0/1(0%)
Hours spent in preschool			116f	0/1(0%)
Environment mental barriers			124f	0/1(0%)
Concern about road safety			124f	0/1(0%)
Park play availability			124f	0/1(0%)
Other children to play with in the neighbourhood			124f	0/1(0%)

A = summary Code is an overall summary of finding for each variable

b N = number of studies that have investigated and reported on possible associations between the variable and physical activity; n = number of studies that report support for the direction of the hypothesized association.

c = percentage % of studies finding an association

d = association shows the direction of the individual/summary association (+/-/?/0) – codes in **bold** are the final result for each correlate; f = reported in a multivariate analysis;
g = reported in a multivariate and univariate analysis; h = association for boys only; i = association for girls only; j = paternal behaviour; k = maternal behaviour; * Less than 4 studies so ? is graded.

Appendix 3.10. – Determinants of Light Physical Activity: Full Table

	Related to physical activity		Unrelated to physical activity	Summary Code[a]	
	Positive Association	Negative Association	No Association		
Determinant Variables	Reference no.	Reference no.	Reference no.	n/N[b] for row (%)[c]	Association [d]
DEMOGRAPHIC AND BIOLOGICAL VARIABLES					
Sex (male)	116f			1/1(100%)	**+**
Ethnicity(white)			116f	0/1(0%)	**0**
Parents education (degree)			116fk	0/1(0%)	**0**
Body Mass Index (BMI)			116f	0/1(0%)	**0**
PHYSICAL ENVIRONMENTAL VARIABLES					
Hours spent at preschool			116f	0/1(0%)	**0**

a = summary Code is an overall summary of finding for each variable

b N = number of times reported associations between the variable and physical activity; n = number of times supporting the direction of the hypothesized association. N = total number of times variables has been investigated

c = percentage % of studies finding an association

d = association shows the direction of the individual/summary association (+/-/?/0) – codes in **bold** are the final result for each correlate

f = reported in a multivariate analysis

g = reported in a multivariate and univariate analysis

h = association for boys only

i = association for girls only

j = paternal behaviour

k = maternal behaviour.

MPA = moderate physical activity.

VPA = vigorous physical activity.
N in **Bold** = High quality studies

<u>Appendix 3.11. – References for Appendices 3.3. – 3.10</u>

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Appendix 5.1. – English version of EY-PAQ

Study ID: ____________

Loughborough University
BRADFORD INSTITUTE FOR HEALTH RESEARCH
BORNINBRADFORD

Early Years Physical Activity Questionnaire

Please complete this questionnaire when your child has worn their physical activity monitor for 7 days. The questionnaire asks about the types of activities your child has been doing in the last 4 weeks, how often and for how long. There are three parts. There are no right or wrong answers and all responses are confidential. Please answer all questions, unless there are questions that you do not wish to answer, you can skip these. If you are unsure about any of the questions please ask a member of school staff or the research team for guidance when you return the questionnaire and activity monitors.

Example answers… In the last month, how many days each week and for how long each day would you say your child has spent doing the following activities at home?

	Less than once a week	How often	For how long each day Please tick one box or write a time if more than one hour daily			
	Yes/ No	Number of days each week. If never put a zero	Up to 15 mins/day	16-30 mins/day	31-60 mins/day	More than an hour/day. Please estimate time
Colouring/drawing/crafting	No	5/7				Hrs: 2 Mins: 30
Sitting playing with toys (e.g. dolls/puzzles/educational play)	No	7/7			✓	Hrs:..... Mins:.....
Watching TV/DVDs	No	7/7				Hrs: 1 Mins: 45
Playing on the computer (do not include physically active games such as Nintendo Wii)	Yes	...../7		✓		Hrs:..... Mins:.....

Thank you in advance for completing the questionnaire

Questionnaire completed by (please circle): Mother / Father / Other (please specify):

Study ID: ___________

Q1. In the last month, how many days each week and for how long each day would you say your child has spent doing the following activities at home?

	Less than once a week	How often	For how long each day Please tick one box or write a time if more than one hour daily			
	Yes/ No	Number of days each week. If never put a zero	Up to 15 mins/day	16-30 mins/day	31-60 mins/day	More than an hour/day, please estimate time
Colouring/drawing/Craft		...../7				Hrs:..... Mins:.....
Sitting playing with toys (e.g. dolls/puzzles/educational play)		...../7				Hrs:..... Mins:.....
Watching TV/DVDs		...../7				Hrs:..... Mins:.....
Playing on the computer (do not include physically active games such as Nintendo Wii)		...../7				Hrs:..... Mins:.....
Sitting listening/singing to music		...../7				Hrs:..... Mins:.....
Reading/being read to		...../7				Hrs:..... Mins:.....
Playing actively inside the house (e.g. dancing, crawling, running, sit and ride toys, push toys, physically active computer games such as Nintendo Wii)		...../7				Hrs:..... Mins:.....
Playing actively in the garden/yard		...../7				Hrs:..... Mins:.....
Engaging in physical activity/active play that makes them sweat or breathe harder		...../7				Hrs:..... Mins:.....

Study ID: ____________

Q2. In the last month, to get from place to place (e.g to the shops, school/groups, park, visiting friends/relatives), on how many days each week and for how long each day would you say your child has spent:

	Less than once a week	How often	For how long each day Please tick one box or write a time if more than one hour daily			
	Yes/ No	Number of days each week. If never put a zero	Up to 15 mins/day	16-30 mins/day	31-60 mins/day	More than an hour/day, please estimate time
In their buggy/pushchair		...../7				Hrs:..... Mins:.....
Walking		...../7				Hrs:..... Mins:.....
Being carried		...../7				Hrs:..... Mins:.....
In the car		...../7				Hrs:..... Mins:.....
On public transport		...../7				Hrs:..... Mins:.....

Q3. In the last month, on how many days each week and for how long each day has your child done the following?

	Less than once a week	How often	For how long each day Please tick one box or write a time if more than one hour daily			
	Yes/ No	Number of days each week. If never put a zero	Up to 15 mins/day	16-30 mins/day	31-60 mins/day	More than an hour/day, please estimate time
Played at the park/playground		...../7				Hrs:..... Mins:.....
Played at Indoor play facilities (e.g. ball pools)		...../7				Hrs:..... Mins:.....

Appendx 5.2. – Urdu transliteration version of the EY-PAQ

Study ID: ____________

Early Years Physical Activity Questionnaire

Hello mera naam …………………hain, mai Born in Bradford se hoon. Aap ka bohut shukriya ke aap humare saat mill rahi hai. Hum yeh jaana chahte hai, ke sargarmiya karte huway, aur TV dekhte huway aap ke bache ne kitna waqt guzzara, pichle mahine ke ekh aam hafte mai. Hum aapke shukar guzaar honge agar aap sab sawaalon ke jawaab de sakay, albata agar aap kuch sawaalon ke jawaab nahi dena chahte toh yeh bhi theek hai. Koi sahi yah galat jawaab nahi hai. Agar koi bhi jawaab dene mai aapko pareshaani ho, toh aap humay sawaal poochne main hichkichaana nahi. Aap ke saare sawaal bharosemand honge. Aap ka naam aur pata iss sawaalnaame main kahin bhi nahi likha jayga. Hum maafi chahte hai, agar koi bhi sawaal aapko burrah lagay.

Example: Pichle mahine main, kitne din aor kitni dair tak aap keh sakti ho ke aap ka bacha ne in jismani sargarmiyaan karta ho ga ghar main ? (Meharbani kar ke nishan lagain)

	Less than once a week	How often	For how long each day Please tick one box or write a time if more than one hour daily			
	Yes/ No	Number of days each week. If never put a zero	Up to 15 mins/day	16-30 mins/day	31-60 mins/day	More than an hour/day. Please estimate time
Colouring/drawing/crafting	No	5/7				Hrs: 2 Mins: 30
Sitting playing with toys (e.g. dolls/puzzles/educational play)	No	7/7			✓	Hrs:….. Mins:…..
Watching TV/DVDs	No	7/7				Hrs: 1 Mins: 45
Playing on the computer (do not include physically active games such as Nintendo Wii)	Yes	……/7		✓		Hrs:….. Mins:…..

Aap ka buhot shukriya in sawaalon ka jawaab denay ka

Study ID: ____________
Questionnaire completed by (please circle): Mother / Father / Other (please specify):

Q1. Pichle mahine main, kitne din aor kitni dair tak aap keh sakti ho ke aap ke bacha ne in jismani sargarmiyaan ki hogi ghar main ? (Meharbani kar ke nishan lagain)

	Hafte mein eik se kam	Kitni baar	Har din Kitni dair tak Please tick one box or write a time if more than one hour daily			
	Yes/ No	Hafte mai Kitni Din If never put a zero	Din mai Pandra minute	Din mai Solan se Thees minute	Din mai Adhay ghante se ekh ghanta	Din mai ekh ghante se ziyada (takriban kitna samay)
Tasweron main rang bharte/taswer banate		...../7				Hrs:..... Mins:.....
Beth kar khilonon se kheltay (e.g. dolls/puzzles educational play)		...../7				Hrs:..... Mins:.....
TV ya DVD dekhtay huway		...../7				Hrs:..... Mins:.....
Computer per kheltay huway (not physically active games such as Nintendo Wii)		...../7				Hrs:..... Mins:.....
Beth kar gana suntay/gana gatay howay		...../7				Hrs:..... Mins:.....
Parhtay howay ya kisi ko parhta suntay howay		...../7				Hrs:..... Mins:.....
Ghar main uchal kood karte howay kheltay howay (nachna, ghutnon per chalna, dorna, khilonon per bethna ya sawari karna, push toys, physically active computer games such as Nintendo Wii)		...../7				Hrs:..... Mins:.....

Study ID: ____________

Ghar ke sehan ya garden main kheltay huway		..../7				Hrs:..... Mins:.....
Ya aisi jismani sargarmiyan jinhain karne se us ki sans phol jati ho ya mehnat karni parti ho		..../7				Hrs:..... Mins:.....

<u>Q2. 2. Pichle mahine, aik jagha se dosri jagha jatay howay (maslan dukanain, school ya groups, park, doston ya rishtedaron ke ghar), aap kya kaho gi kay aap kay bache ne aik haftay main kitne din aur ekh din main kitne dair ke liya guzaara:</u>

	Hafte mein eik se kam	Kitni baar	Har din Kitni dair tak Please tick one box or write a time if more than one hour daily			
	Yes/ No	Hafte mai Kitni Din If never put a zero	Din mai Pandra minute		Yes/ No	Hafte mai Kitni Din If never put a zero
buggy/pushchair main		..../7				Hrs:..... Mins:.....
Chaltay howay		..../7				Hrs:..... Mins:.....
Kisi ki goud main		..../7				Hrs:..... Mins:.....
Gahri main		..../7				Hrs:..... Mins:.....
public transport main		..../7				Hrs:..... Mins:.....

Study ID: ____________

Q3. Pichle mahine, kitne din har haftay aur kitni dair aapke bache ne ye darjzael kaam kiye hai?

	Hafte mein eik se kam	Kitni baar	Har din Kitni dair tak Please tick one box or write a time if more than one hour daily			
	Yes/ No	Hafte mai Kitni Din If never put a zero	Din mai Pandra minute		Yes/ No	Hafte mai Kitni Din If never put a zero
Park ya playground mein khelte hue		**...../7**				Hrs:..... Mins:.....
Andar jo khelney ki sahooleat hain unko istmaal kia hai (e.g. ball pools)		**...../7**				Hrs:..... Mins:.....

Appendix 6 – Correlates of toddlers daily MVPA using univariate linear regression.

Table 6: Correlates of two year old childrens daily MVPA using univariate linear regression.

Potential Correlates	**All** daily MVPA (n=837)	**WB** daily MVPA (n=333)	**SA** daily MVPA (n=470)
	β (95% CI)	β (95% CI)	β (95% CI)
Sleep Total (hours)	-0.05 (-3.4, 3.3)	2.7 (-3.5, 8.9)	-1.0 (-5.0, 3.1)
Sleep day (hours)	0.6 (-2.9, 4.1)	-0.6 (-6.4, 5.3)	0.7 (-4.0, 5.3)
Sleep night (hours)	-1.4 (-5.0, 2.3)	3.0 (-2.9, 8.9)	-3.4, (-8.4, 1.6)
Sex			
Boys	Reference	Reference	Reference
Girls	-7.7 (-20.0, 4.6)*	-5.6 (-24.9, 13.6)	-10.8 (-27.6, 5.9)*
Season			
Summer	Reference	Reference	Reference
Spring	-15.7 (-30.6, -0.9)*	-2.9 (-25.7, 19.9)	-25.1 (-45.5, -4.8)*
Autumn	-23.5 (-51.0, 4.0)*	-51.5 (-95.0, -7.9)*	0.3 (-41.6, 42.2)
Winter	-51.8 (-68.8, -34.8)*	-30.8 (-57.8, -3.7)*	-59.7 (-82.4, -37.0)*
Age (months)	3.7 (-2.8, 10.1)*	-2.7 (-13.2, 7.7)	6.9 (-2.0, 15.8)
Language			
English	Reference	Reference	Reference
Urdu	-91.6 (-271.6, 88.3)	~	~
Mirpuri	-0.1 (-15.7, 15.5)	~	~
Other	-0.9 (180.8, 179.0)	~	~
Mother Weight (kg)	-0.1 (-0.5, 0.3)	-0.3 (-0.9, 0.3)	-0.1)-0.6, 0.5)
Child Weight (kg)	-0.4 (-4.3, 3.5)	-3.4 (-9.4, 2.7)	2.1 (-3.1, 7.3)
Child Height (cm)	-0.3 (-1.1, 1.8)	0.2 (-1.6, 2.0)	1.1 (-1.6, 3.7)
Mother Health			
Excellent	Reference	Reference	Reference
Very Good	17.9 ('-3.9, 39.7)*	12.6 (-20.6, 45.8)	21.7 (-8.0, 51.4)
Good	9.2 (-11.6, 29.9)	12.6 (-19.3, 44.5)	9.7 (-18.6, 37.9)
Fair	-5.2 (-32.4, 21.9)	-11.2 (-53.8. 31.4)	-9.0 (-45.7, 27.8)
Poor	9.3 (-38.1, 56.7)	-2.0 (-79.3, 75.3)	0.8 (63.6, 62.1)
Child Health			
Excellent	Reference	Reference	Reference
Very Good	10.0 (-7.5, 27.6)*	11.9 (-14.9, 38.8)	8.4 (-15.8, 32.5)
Good	11.8 (-5.5, 29.2)*	8.3 (-19.1, 35.7)	11.2 (-12.5, 34.8)
Fair	37.1 (4.0, 70.3)*	44.9 (-2.0, 91.8)#*	20.3 (-29.4, 69.9)
Poor	47.1 (-22.2, 116.4)*	55.0 (-48.7, 158.7)	40.4 (-52.9, 133.8)
Mothers Relationship Status			
Married	Reference	Reference	Reference
Re-married	-12.0 (-192.0, 168.0)	~	-8.9 (-191.2, 173.3)
Single (never married)	2.5 (-16.9, 12.0)	-12.7 (-34.0, 8.7)	6.5 (-13.9, 26.9)
Seperated (but still legally married)	16.3 (-66.7, 34.2)	69.2 (-19.1, 157.5)#*	-42.12 (-107.2, 23.0)#*
Divorced	-36.8 (-127.01, 53.4)	67.8 (-107.7, 243.3)	69.5 (-175.0, 36.0)
Living Status			
Living with childs father	Reference	Reference	Reference
living with another partner	10.7 (-41.5, 63.0)	-30.2 (-102.5, 42.2)	52.5 (-22.2, 127.3)
not living with a partner but in a relationship	20.3 (-14.3, 54.8)	46.0 (-7.8, 100.0)#*	10.0 (-36.3, 56.3)
not in relationship and not living with a partner	-1.4 (-22.6, 19.9)	8.9 (-24.8, 42.6)	-12.6 (-42.7, 17.5)
Hospital visit in the last 6 months			
No	Reference	Reference	Reference
Yes	2.5 (-22.7, 27.8)	15.2 (-26.3, 56.7)	-3.3 (-35.3, 28.7)

Mother ever breast fed			
Yes	Reference		
No	1.7 (-15.0, 11.7)	-11.5 (-32.4, 9.3)	5.6 (-12.8, 23.9)
Mother ever smoked			
No	Reference	Reference	Reference
Yes	5.1 (-12.1, 22.4)	-14.8 (-40.6, 11.2)	21.3 (-2.4, 44.9)*
When Stopped Breast feeding			
Still breast feeding	Reference	Reference	Reference
Stopped recently	-1.0 (-14.8, 12.9)	11.8 (-9.4, 33.1)	-11.4 (-30.4, 7.7)
don't know	58.2 (-32.8, 149.2)	~	53.1 (-39.5, 145.7)
TV viewing during weekday (hours)	0.4 (-1.1, 1.8)	-0.7 (-3.1, 1.6)	1.1 (-0.8, 3.1)
TV viewing during weekends (hours)	0.6 (-0.9, 2.0)	-0.3 (-2/6, 2.1)	1.3 (-0.7, 3.2)
TV Screen Time before 6pm on Weekdays			
None	Reference	Reference	Reference
<1 hour	-2.2 (-21.9, 17.4)	3.9 (-26.0, 33.6)	2.0 (-25.7, 29.6)
1-2 hours	-3.4 (-23.5, 16.7)	-0.6 (-31.1, 29.9)	-3.1 (-31.3, 25.1)
2-3 hours	-5.4 (-31.1, 20.3)	13.6 (-26.1, 53.3)	-20.7 (-56.3, 14.9)
3-4 hours	-13.0 (-47.7, 21.5)	-27.2 (-86.1, 31.6)	-6.0 (-50.3, 38.3)
>4 hours	-8.5 (-47.7, 30.6)	-4.5 (-63.3, 54.4)	-13.2 (-67.6, 41.1)
TV Screen Time after 6pm on Weekdays			
None	Reference	Reference	Reference
<1 hour	-2.1 (-15.8, 11.6)	3.5 (-17.6, 24.6)	-9.5 (-28.3, 9.3)
1-2 hours	-0.6 (-19.7, 18.5)	-8.4 (-40.2, 23.4)	-2.4 (-27.4, 22.6)
2-3 hours	9.3 (-28.5, 47.1)	-10.9 (-79.0, 57.2)	8.3 (-43.8, 60.4)
3-4 hours	57.7 (-144.9, 63.6) #	60.6 (-64.9, 186.1)##	53.1 (-76.6, 182.8)##
>4 hours	-40.6 (-144.9, 43.6)	-38.7 (-164.2, 86.8)##	-46.7 (-229.7, 136.2)##
TV Screen Time before 6pm on Weekend days			
None	Reference	Reference	Reference
<1 hour	-1.0 (-19.1, 17.1)	13.8 (-14.2, 41.8)	-3.9 (-28.6, 20.9)
1-2 hours	1.9 (-16.8, 20.6)	5.3 (-23.4, 34.0)	2.7 (-23.1, 28.6)
2-3 hours	-4.7 (-28.4, 18.9)	14.7 (-23.5, 52.8)#	-20.7 (-52.6, 11.1)*
3-4 hours	-25.7 (-56.5, 5.2)*	-17.8 (-70.1, 34.4)##	-34.7 (-74.6, 5.2)##*
>4 hours	-4.0 (-45.1, 37.1)	26.8 (-36.2, 89.7)##	-21.7 (-76.1, 32.7)##
TV Screen Time after 6pm on Weekend days			
None	Reference	Reference	Reference
<1 hour	-7.2 (-21.2, 6.8)	1.5 (-20.2, 23.2)	-16.8 (-36.0, 2.4)*
1-2 hours	-3.2 (-21.5, 15.0)	-2.6 (-31.9, 26.7)	-7.2 (-31.7, 17.3)
2-3 hours	6.7 (-30.5, 43.9)	-11.7 (-72.1, 48.8)##	10.5 (-45.9, 67.0)##
3-4 hours	13.8 (-76.8, 104.4)#	60.3 (-65.3, 185.9)##	-33.4 (-163.3, 96.5)##
>4 hours	11.5 (-69.7, 92.6)#	-39.0 (-164.5, 86.6)##	43.8 (-62.5, 150.1)##
Perceptions of childs weight			
Just right	Reference	Reference	Reference
much to low	17.4 (-35.0, 69.8)	82.1 (-42.7, 206.8)#*	5.5 (-52.9, 63.8)
a little to low	-1.9 (-18.6, 14.7)	-0.9 (-26.8, 25.0)	-9.5 (-32.5, 13.4)#
a litle to high	4.1 (-28.5, 36.7)	-20.7 (-64.7, 23.4)##	41.2 (-12.2, 94.6)#*
much to high	9.2 (-81.1, 99.4)#	-74.1 (-250.2, 102.0)##	37.6 (-67.9, 143.2)#
Childs weight compared to others			
About the same	Reference	Reference	Reference
much thinner	9.4 (-31.6, 50.4)#	42.7 (-36.9, 122.3)##	4.9 (-45.0, 54.9)##
a little bit thinner	9.7 (-4.8, 24.2)*	-2.6 (-25.1, 19.8)	14.9 (-5.3, 35.1)*
a little bit heavier	3.9 (-14.2, 22.1)	-0.12 (-28.8, 28.5)	7.0 (-17.2, 31.2)
much heavier	-77.2 (-181.2, 26.8)#*	-95.7 (-220.6, 29.2)	-46.6 (-22.9.2, 136.1)##
Mothers weekly MPA minutes	-0.8 (-0.23, 0.07)	0.1 (-0.17, 0.36)	-0.16 (-0.34, 0.02)*
Mothers weekly VPA minutes	-0.10 (-0.23, 0.02)*	-0.08 (-0.27, 0.11)	-0.12 (-0.30, 0.06)*
Mothers weekly PA minutes	-0.02 (-0.4, 0.01)	-0.02 (-0.06, 0.02)	-0.01 (-0.04, 0.02)
Mothers physical activity status			
Active	Reference	Reference	Reference
Inactive	5.1 (-8.7, 18.8)	5.0 (-16.7, 26.3)	2.7 (-15.8, 21.3)
Sedentary	-4.6 (-25.9, 16.7)	-4.6 (-38.9, 29.7)	-3.4 (-32.9, 26.1)

Mothers number of activity sessions	-0.62 (-2.2, 0.9)	-1.8 (-4.4, 0.8)*	0.4 (-1.7, 2.4)
Mothers weekly sitting time	-0.01 (-0.03, 0.1)	-0.01 (-0.04, 0.02)	0.01 (-0.03, 0.03)
Mothers daily TV viewing	-0.30 (-4.1, 3.5)	0.58 (-5.33, 6.5)	-0.46 (-5.8, 4.8)
Perceptions of child being as active as peers			
Similarly active	Reference	Reference	Reference
generally more active	9.2 (-3.6, 22.0)*	-9.5 (-29.7, 10.8)	22.1 (4.8, 39.5)**
generally less active	12.2 (-25.3, 49.8)#	10.9 (-48.9, 70.7)#	10.4 (-39.3, 60.1)#
Child enjoys physical activity			
Agree	Reference	Reference	Reference
neither agree or disagree	-23.8 (-87.6, 40.1)	-8.4 (-80.9, 64.1)	8.8 (-33.8, 51.5)
disagree	2.6 (-33.2, 38.5)#	16.5 (-72.1, 105.0)#	-63.3 (-154.8, 28.1)#*
Important child does not watch to much TV			
Agree	Reference	Reference	Reference
neither agree or disagree	-9.3 (-25.8, 7.3)	-6.6 (-31.2, 17.9)	-14.6 (-38.2, 9.1)*
disagree	-3.6 (-30.0, 22.7)	-22.4 (-70.6, 25.8)#	7.2 (-26.4, 40.8)
Important to take child places to be active			
Agree	Reference	Reference	Reference
neither agree or disagree	12.8 (-22.9, 47.4)	0.3 (-62.5, 63.2)#	7.4 (-40.5, 55.2)#
disagree	22.8 (-57.9, 103.4)	#	24.5 (-57.5, 106.5)#
How often has mother or partner encouraged child to play active games in the last month			
Everyday	Reference	Reference	Reference
5-6 times a week	-23.4 (-50.3, 3.4)*	-64.8 (-105.6, -24.0)#*	1.9 (-34.3, 38.0)#
2-4 times a week	2.5 (-13.5, 18.4)	7.8 (-16.5, 32.2)	2.2 (-19.7, 24.1)
once a week	-11.0 (-35.7, 13.6)	-38.6 (-80.3, 3.2)#*	10.9 (-21.6, 43.3)#
1-3 times this month	-3.6 (-46.8, 39.6)	-15.0 (-137.9, 107.9)##	13.9 (-38.3, 66.1)##
Never	7.6 (-11.0, 26.2)	0.8 (-28.3, 29.9)	8.3 (-17.3, 34.0)
How often has mother or partner played an actively with child in the last month			
Everyday	Reference	Reference	Reference
5-6 times a week	-13.7 (-36.5, 9.1)*	-20.6 (-54.0, 12.8)#	-6.7 (-37.9, 24.5)#
2-4 times a week	6.6 (-8.8, 22.0)	-3.1 (-26.8, 20.6)	14.9 (-6.5, 36.3)*
once a week	-11.8 (-34.7, 11.1)	5.0 (-38.5, 48.5)#	-13.2 (-42.4, 16.0)
1-3 times this month	-10.1 (-45.7, 25.6)	-17.5 (-74.7, 39.7)##	-9.7 (-58.3, 38.9)##
Never	-3.8 (-30.4, 22.8)	-19.4 (-70.0, 31.2)##	6.5 (-27.5, 40.4)#
How often mother or partner taken child to places to be physically active in the last month			
Everyday	Reference	Reference	Reference
5-6 times a week	31.1 (-2.0, 64.1)*	45.1 (-7.2, 97.3)#*	22.6 (-20.0, 65.1)#
2-4 times a week	13.2 (-10.6, 37.0)	10.2 (-28.0, 48.4)	13.5 (-17.5, 44.6)
once a week	1.4 (-23.5, 26.2)	27.6 (-12.0, 67.3)	-18.9 (-51.4, 13.6)
1-3 times this month	6.0 (-20.8, 32.8)	-9.4 (-52.1, 33.3)	17.3 (-17.7, 52.3)
Never	11.4 (-17.0, 39.8)	8.3 (-40.0, 56.7)#	17.2 (-19.5, 53.8)
How often child watched TV at meal times			
Never	Reference	Reference	Reference
1-3 times this month	-24.8 (-48.9, -0.7)*	18.8 (-54.1, 16.5)	-29.8 (-63.8, 4.1)*
once a week	-22.9 (-48.5, 2.7)*	6.6 (-36.7, 49.9)	-32.7)-66.2, 0.8)*
2-4 times a week	-10.7 (-28.8, 7.3)	-13.2 (-40.3, 13.9)	-6.9 (-32.0, 18.2)
5-6 times a week	12.7 (-15.7, 41.1)	24.7 (-22.0, 71.3)	-0.06 (-38.5, 38.4)
Everyday	-2.9 (-18.7, 12.8)	4.0 (-21.3, 29.2)	-2.1 (-23.4, 19.2)
How often child gone to bed at a regular time			
Everyday	Reference	Reference	Reference
5-6 times a week	10.0 (-7.9, 27.9)	-6.4 (-32.4, 19.6)	19.3 (-6.7, 45.2)
2-4 times a week	3.6 (-16.8, 24.0)	-11.7 (-42.6, 19.2)	18.0 (-10.7, 46.7)
once a week	29.9 (-14.4, 74.1)#*	57.0 (-10.4, 124.5)##*	25.8 (-35.8, 87.4)

1-3 times this month	-1.7 (-40.0, 36.5)	-4.7 (-84.1, 74.7)	3.5 (-41.8, 48.9)
Never	5.2 (-34.7, 45.2)	-0.3 (-63.6, 62.9)	4.3 (-49.3, 57.9)
How often child played ball games in the house			
Everyday	Reference	Reference	Reference
5-6 times a week	18.6 (-11.6, 48.8)	21.3 (-25.9, 68.5)##	19.8 (-21.4, 61.1)##
2-4 times a week	4.2 (-12.0, 20.4)	1.7 (-24.1, 27.5)	4.0 (-18.0, 25.9)
once a week	0.7 (-21.0, 22.5)	4.7 (-30.0, 39.4)	-5.8 (-35.2, 23.6)
1-3 times this month	-23.0 (-47.9, 1.9)#*	-14.1 (-49.6, 21.4)#	28.2 (-64.2, 7.8)#
Never	9.8 (-8.2, 27.7)	16.9 (-11.5, 45.4)	6.7 (-18.1, 31.5)
How often child ran or ridden tricylce in the house			
Everyday	Reference	Reference	Reference
5-6 times a week	-14.8 (-47.0, 17.4)	-46.9 (-107.1, 13.4)##*	-19.7 (-62.5, 23.0)##
2-4 times a week	-8.2 (-26.8, 10.3)	-19.9 (-48.9, 9.1)*	3.6 (-21.8, 28.9)
once a week	-11.7 (-39.3, 15.9)	1.3 (-38.9, 41.6)#	-18.7 (-57.3, 20.0)#
1-3 times this month	-26.2 (-56.4, 4.1)#*	-33.0 (-73.3, 7.3)#*	-10.3 (-57.7, 37.0)#
Never	-5.3 (-20.4, 9.7)	-0.6 (-24.0, 22.9)	-8.1 (-28.7, 12.5)
Limited time watching DVDs in the last month			
Everyday	Reference	Reference	Reference
5-6 times a week	39.1 (8.2, 70.0)#*	63.4 (9.3, 117.4)##*	25.9 (-12.7, 64.5)##*
2-4 times a week	25.7 (5.5, 45.9)*	33.7 (2.5, 64.9)*	25.7 (-2.1, 53.4)*
once a week	32.6 (6.9, 58.3)*	46.6 (11.7, 81.7)*	7.9 (-32.6, 48.4)##
1-3 times this month	20.0 (-14.4, 54.4)	-13.2 (-63.9, 37.4)##	24.5 (-28.5, 77.6)#
Never	21.5 (5.9, 37.1)*	17.6 (-7.9, 43.1)	23.9 (3.2, 44.5)
Limited time playing outside in the last month			
Never	Reference	Reference	Reference
1-3 times this month	11.8 (-53.6, 29.9)	-3.1(-45.1, 38.9)#	-0.7 (-34.1, 32.6)#
once a week	7.0 (-53.6, 29.9)	24.6 (-17.4, 66.6)#	-37.3 (-68.2, -6.4)#*
2-4 times a week	25.3 (-6.8, 57.4)*	19.2 (-6.2, 44.6)	-9.6 (-33.7, 14.5)
5-6 times a week	-39.1 (-107.0, 28.9)	32.1 (-13.0, 77.3)#*	11.9 (-27.4, 51.2)#
Everyday	-40.8 (-66.0, 15.6)*	6.5 (-21.5, 34.5)	-4.3 (-28.6, 20.1)
Barrier for child to be active : cost of clubs or facilities			
Never	Reference	Reference	Reference
1-3 times this month	-6.0 (-28.6, 16.5)	-3.1 (-38.4, 32.2)#	-3.2 (-34.1, 27.7)#
once a week	-5.9 (-34.1, 22.3)	20.6 (-23.1, 64.3)#	-22.1 (-59.0, 14.6)#
2-4 times a week	12.5 (-22.1, 47.1)	31.8 (-21.9, 85.6)##	-10.1 (-56.4, 36.3)##
5-6 times a week	86.1 (-3.8, 176.1)'#*	176.5 (1.5, 351.6)##*	56.3 (-48.9, 161.5)##
Everyday	-31.8 (-78.7, 15.0)#*	42.1 (-30.0, 114.2)##	-77.7 (-142.5, -12.8)##*
Barrier for child to be active : travel to places where child can be active			
Never	Reference	Reference	Reference
1-3 times this month	-15.2 (-39.0, 8.5)	-6.2 (-44.6, 32.1)#	-35.7 (-67.4, -4.1)#*
once a week	-25.3 (-50.2, -0.4)#*	3.3 (-33.6, 40.2)#	-52.7 (-87.7, -17.8)#*
2-4 times a week	11.8 (-11.8, 35.4)	20.2 (-14.3, 54.7)#	-1.5 (-35.3, 32.4)#
5-6 times a week	-30.9 (-91.1, 29.4)	95.1 (-80.8, 271.0)##	-53.0 (-121.9, 16.0)##*
Everyday	1.2 (-26.2, 28.6)	31.6 (-15.2, 78.3)##*	-16.8 (-52.4, 18.7)#
Barrier for child to be active: weather			
Never	Reference	Reference	Reference
1-3 times this month	-4.9 (-23.4, 13.6)	-0.9 (-27.5, 27.4)	-8.2 (-34.4, 18.0)
once a week	-14.6 (-34.1, 4.8)*	15.3 (-14.0, 44.6)	-36.8 (-64.2, -9.4)*
2-4 times a week	5.0 (-11.2, 21.2)	10.0 (-16.4, 36.5)	-1.2 (-22.8, 20.3)
5-6 times a week	-20.9 (-55.7, 13.9)	11.7 (-43.6, 66.9)##	-41.2 (-86.1, 3.8)##*
Everyday	-27.6 (-53.2, -1.9)#*	-24.3 (-73.7, 25.2)##	-30.7 (-63.3, 2.0)#*
Barrier for child to be active: mother to busy			
Never	Reference	Reference	Reference
1-3 times this month	-18.8 (-39.7, 2.0)*	8.6 (-39.0, 21.8	-25.5 (-55.8, 4.8)#*
once a week	-7.8 (-30.0, 14.3)	13.9 (-18.7, 46.5)	-27.3 (-58.7, 4.0)#*
2-4 times a week	-1.3 (-21.9, 19.3)	-5.9 (-39.3, 27.6)#	-9.7 (-37.8, 18.3)
5-6 times a week	-11.7 (-57.3, 33.9)	39.8 (-85.4, 165.0)##	-20.0 (-71.5, 31.6)##
Everyday	-1.4 (-28.7, 26.0)	1.9 (-45.2, 49.0)##	-10.0 (-45.9, 26.0)#

Barrier for child to be active: fear child will be hurt			
Never	Reference	Reference	Reference
1-3 times this month	2.6 (-36.6, 31.4)	21.4 (-30.4, 73.3)##	-18.4 (-63.5, 26.6)##
once a week	-44.8 (-80.6, -9.0)#*	-51.8 (-131.2, 27.5)##*	-37.7 (-80.5, 5.0)##*
2-4 times a week	16.1 (-11.5, 43.7)	20.2 (-29.7, 70.1)##	13.8 (-21.3, 48.8)#
5-6 times a week	13.6 (-54.5, 81.8)	-25.8 (-127.9, 76.2)##	91.4 (-13.9, 196.7)##*
Everyday	8.9 (-14.2, 32.0)	18.2 (-20.7, 57.2)#	0.6 (-29.6, 30.9)#
Barrier for child to be active: no children to play with			
Never	Reference	Reference	Reference
1-3 times this month	0.3 (-33.7, 34.3)	11.6 (-40.4, 63.5)##	-6.5 (-51.5, 38.4)##
once a week	-34.2 (-73.1, 4.7)#*	6.3 (-45.6, 58.2)##	-81.9 (-140.0, -23.8)##*
2-4 times a week	-12.1 (-36.8, 12.6)	-19.7 (-60.5, 21.1)#	-9.5 (-41.5, 22.5)#
5-6 times a week	-14.9 (-83.2, 53.3)	-41.4 (-143.6, 60.8)##	41.0 (-64.2, 146.1)##
Everyday	-14.2 (-59.6, 31.2)	-22.1 (-101.5, 57.4)##	3.1 (-58.1, 64.3)##
Barrier for child to be active: no adult to supervise child playing			
Never	Reference	Reference	Reference
1-3 times this month	-9.8 (-51.6, 32.0)	4.5 (-62.8, 71.8)##	-16.9 (-70.5, 36.7)##
once a week	-2.5 (-40.6, 35.6)	12.0 (-60.6, 84.6)##	-5.6 (-53.7, 42.5)##
2-4 times a week	7.7 (-30.4, 45.8)	-1.6 (-64.6, 61.5)##	6.2 (-43.5, 55.9)##
5-6 times a week	-22.0 (-126.15, 82.2)		-20.8 (-126.8, 85.2)##
Everyday	5.2 (-30.1, 40.4)	28.0 (-21.9, 77.9)##	1.7 (-54.2, 57.6)##
Barrier for child to be active: mother can not take on her own			
Never	Reference	Reference	Reference
1-3 times this month	-21.4 (-48.1, 5.4)	10.7 (-28.3, 49.6)#	-42.9 (-81.0, -4.7)#*
once a week	0.8 (-30.7, 32.2)	25.7 (-33.8, 85.2)##	-13.8 (-52.6, 25.1)##
2-4 times a week	7.6 (-21.5, 36.8)	-8.2 (-62.2, 45.8)##	3.0 (-35.8, 41.9)##
5-6 times a week	69.5 (15.0, 123.9)##*	74.2 (-14.3, 162.6)##*	82.1 (7.7, 156.5)##*
Everyday	-14.6 (-41.6, 12.4)	-5.0 (-51.6, 41.6)##	-23.7 (-58.6, 11.2)#*
Free space for child play outside in surrounding neighbourhood			
Yes	Reference	Reference	Reference
No	-0.7 (-17.2, 15.8)	1.5 (-21.5, 24.5)	-2.1 (-83.3, 79.2)
Feel neighbourhood is unsafe for child to play			
No	Reference	Reference	Reference
Yes	1.7 (-13.2, 16.6)	-9.2 (-31.9, 13.4)	4.0 (-16.5, 24.4)
Amount of time spent at nursery/preschool each week			
Do not attend	Reference	Reference	Reference
Part time	-13.1 (-29.6, 3.4)*	-49.7 (-92.0, -7.4)*	10.4 (-31.5, 52.3)
Full time	1.6 (-24.6, 27.8)	-12.2 (-49.3, 24.8)	10.8 (-27.1, 48.7)
Parenting: feeling depressed			
None of the time	Reference	Reference	Reference
A little of the time	7.9 (-7.4, 23.3)	11.1 (-12.9, 35.2)	4.3 (-16.5, 25.1)
Some of the time	16.6 (-2.4, 35.7)*	4.7 (-25.1, 34.5)	24.9 (-1.4, 51.1)*
Most of the time	-18.9 (-57.2, 19.4)	-35.1 (-114.7, 44.5)##	-12.1 (-57.6, 33.3)##
All of the time	-1.7 (-56.4, 53.1)	48.6 (-31.0, 128.3)##	-43.2 (-118.2, 31.8)##
Parenting: feeling hopelessness			
None of the time	Reference	Reference	Reference
A little of the time	15.5 (-2.8, 33.7)*	15.2 (-12.1, 42.5)	10.6 (-15.2, 36.5)
Some of the time	11.4 (-8.9, 31.8)	-5.2 (-40.9, 30.5)#	16.2 (-10.2, 42.6)
Most of the time	-18.4 (-63.9, 27.1)	29.8 (-49.8, 109.3)##	-40.1 (-95.8, 15.6)##*
All of the time	-46.1 (-136.2, 43.9)	-30.9 (-155.9, 94.1)##	-62.2 (-191.2, 66.8)##
Parenting: feeling restlessness			
None of the time	Reference	Reference	Reference
A little of the time	3.0 (-12.1, 18.1)	6.2 (-17.1, 29.4)	-4.9 (-25.6, 15.9)
Some of the time	8.4 (-9.5, 26.4)	3.7 (-24.0, 31.5)	12.9 (-11.8, 37.6)
Most of the time	13.2 (-20.6, 47.0)	29.7 (-30.6, 90.0)##	-2.0 (-44.2, 40.1)##
All of the time	-47.6 (-166.0, 20.8)##*	3.1 (-99.6, 1-5.8)##	-86.2 (-177.9, 5.4)##*
Parenting: feeling everything is an effort			
None of the time	Reference	Reference	Reference
A little of the time	5.0 (-10.0, 20.1)	6.6 (-16.2, 29.4)	6.7 (-14.3, 27.7)
Some of the time	9.9 (-8.0, 27.8)	16.4 (-12.8, 45.5)	10.0 (-14.4, 34.4)

Most of the time	-5.0 (-34.7, 24.7)	-10.7 (-63.3, 41.8)##	7.8 (-29.9, 45.5)##
All of the time	3.4 (-36.8, 43.6)	36.5 (-36.6, 109.6)##	-7.2 (-55.8, 41.4)##
Parenting: feeling of worthlessness			
None of the time	Reference	Reference	Reference
A little of the time	-4.2 (-24.2, 15.7)	-14.3 (-45.1, 16.6)	-1.6 (-28.9, 25.6)
Some of the time	8.3 (-21.7, 38.3)	30.3 (-21.6, 82.2)##	5.5 (-32.9, 44.0)##
Most of the time	5.3 (-47.1, 57.7)	-8.0 (-96.7, 80.7)##	-8.1 (-77.9, 61.6)##
All of the time	-21.0 (-125.2, 83.2)	21.7 (-154.7, 198.1)##	-41.6 (-171.2, 88.0)##
IMD_score	-0.02 (-0.4, 0.3)	-0.3 (-0.8, 0.2)	0.2 (-0.4, 0.7)
Mothers Employment status			
Looking after family home	Reference	Reference	Reference
maternity leave	-7.9 (-23.3, 7.4)	-13.2 (-38.0, 11.6)	-0.6 (-20.9, 19.7)
Student	9.0 (-32.1, 50.2)	24.8 (-43.2, 92.8)##	-0.8 (-57.0, 55.4)##
Self-Employed	-19.2 (-61.4, 23.0)	-1.0 (-53.7, 51.8)##	48.9 (-118.8, 21.0)##
Work for an employer	-6.7 (-22.5, 9.2)	24.8 (-43.2, 92.8)	-5.2 (-27.8, 17.3)
Regular Childcare			
Yes	Reference	Reference	Reference
No	2.4 (-10.7, 15.6)	10.4 (-9.9, 30.6)	-8.1 (-26.3, 10.1)
No Passive toys in the home	-1.9 (-9.8, 5.9)	1.0 (-13.3, 15.3)	-3.8 (-13.5, 5.9)
No Active toys in the home	3.7 (0.4, 7.0)*	4.6 (-0.6, 9.9)*	2.1 (-2.4, 6.5)
Mothers parenting self-efficacy score	-0.1 (-1.3, 1.1)	-0.6 (-2.6, 1.3)	0.2 (-1.3, 1.8)
Mothers parenting warmth score	-1.4 (-4.0, 1.3)	1.6 (-2.6, 5.8)	-2.3 (-5.9, 1.3)
Mothers parenting hostile score	-0.1 (-1.1, 1.1)	-0.3 (-2.2, 1.6)	0.6 (-0.9, 2.1)
BMIz Score	-0.3 (-8.8, 8.3)	-1.3 (-13.7, 11.1)	2.4 (-10.1, 14.8)
Mothers education			
Higher than A-level	Reference	Reference	Reference
A-level	-26.1 (-50.9, -1.2)*	-30.2 (-71.7, 11.2)*	-20.6 (-53.7, 12.4)
5 GCSE	-8.3 (-25.0, 8.5)	-8.2 (-34.2, 17.8)#	-10.3 (-33.6, 12.9)#
<5 GCSE	-11.4 (-29.0, 6.2)	-6.6 (-35.4, 22.2)	-12.7 (-36.4, 10.9)
Other	-19.2 (-41.0, 2.6)*	-17.8 (-48.1, 12.4)#	-33.3 (-68.9, 2.3)*

Notes:
* $p<0.2$
# significant value is based on less than 10% of sample
less than 5%
332 WB 5%(n=17); 10% (n=33)
469 SA 5% (n=23); 10% (n=47)
850 Total 5% (n=43); 10% (n=85)
β represent the difference in MVPA per 1 unit increase in continuous variables or relative difference to reference group in categorical variables. 95% CI = confidence intervals.