Accelerometers in Young Children: Methodological Considerations and Cross-sectional and Longitudinal Associations with Motor Abilities, Physical Fitness, and Cognitive Function

by

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ABSTRACT

Physical activity plays an important role during early childhood and has favourable associations with numerous health outcomes. It is thought that lifestyle and physical activity behaviours may develop within the first five years of life, making the early years an optimal time for targeted intervention and observation. Accelerometers are valid and reliable devices that allow researchers to quantify large amounts of free-living data in young child populations. However, use of these devices are accompanied by many methodological decisions which can create inconsistencies and limit comparability within the literature. The focus of this thesis was to extensively review current methods being used to analyse accelerometer data from young children, examine how certain methodologies affect interpretation of accelerometer outputs, and observe subsequent cross-sectional and longitudinal associations between physical activity and health. An extensive review revealed that hundreds of published studies use accelerometers with a wide variety of data collection and analysis methods to track movement in young children. Applying different thresholds or cutpoints to quantify movement behaviours into specific intensities of movement demonstrated that choice of cutpoint significantly impacts amounts of time spent in each intensity as well as the number of children categorized as meeting physical activity guidelines. A cross-sectional analysis showed that preschool-aged children who met physical activity guidelines did not have greater levels of individual motor abilities compared to children not meeting guidelines, however sports club membership may influence motor ability development. In a longitudinal analysis, children who met physical activity guidelines during early childhood were more likely to meet guidelines during later childhood/adolescence. Additionally, performance on certain physical fitness tests at baseline also predicted greater amounts of time in physical activity and meeting physical activity guidelines at follow-up. Interestingly, meeting physical activity guidelines showed no associations with cognitive function, and some physical fitness tests showed statistically significant associations, but models did not show a substantial goodness of fit. In summary, future work should continue to investigate associations between meeting physical activity guidelines and health outcomes in young children. Given the importance of this work, we strongly encourage researchers to adapt and apply our recommended, standardized accelerometry reporting practice.

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SUMMARY OF CONTRIBUTIONS

The following thesis is presented in manuscript form and is comprised of seven chapters. Chapter 1 provides a brief introduction to this Doctoral thesis and outlines the essential role that physical activity plays in childhood growth and development, cardiometabolic health and motor competence and provides a brief overview regarding the challenges associated with published movement guidelines, the use of accelerometers to track free-living movements and finally an overview of the thesis objectives, research questions and hypotheses. Chapter 2 is a Scoping Review which reports the methods used for collecting and processing accelerometer data from young children; this manuscript is in preparation for submission. Chapter 3 explored how different Actigraph cutpoints impact physical activity and sedentary behaviour outcomes in young children; this manuscript has been submitted and is currently under review. Chapter 4 is a bridging chapter that summarizes findings from Chapters 2 and 3, and highlights subsequent research aims of Chapters 5 and 6. Chapter 5 is a published manuscript which explored associations between individual motor abilities and physical activity measures in a cross section of preschool-aged children. Chapter 6 was a study conducted to explore longitudinal relationships of physical activity, fitness, and cognitive development in young children; this manuscript is in preparation for submission. Lastly, Chapter 7 is an integrated discussion and conclusion of findings from Chapters 2-6 and offers suggestions for future research.

<u>Summary of contributions to the thesis:</u>

1. **Becky Breau**, Hannah J. Coyle-Asbil and Lori Ann Vallis. The use of accelerometers in young children: A methodological scoping review. (Manuscript in preparation for the *Journal for the Measurement of Physical Behaviour.*) **(Chapter 2)**

   Contributions: BB was responsible for conceptualization of the study, co-responsible for creation of search strategies, running database searches and data extraction. BB was responsible for data analysis, interpretation, and manuscript writing.
   Institution: University of Guelph, Guelph, ON, Canada
   Supervisor: Prof. Lori Ann Vallis
2. **Becky Breau,** Hannah J. Coyle-Asbil, Jess Haines, David W.L. Ma, and Lori Ann Vallis; on behalf of the Guelph Family Health Study (2021). Actigraph cutpoints impact physical activity and sedentary behaviour outcomes in young children. (Manuscript in preparation for the *Journal for the Measurement of Physical Behaviour*). **(Chapter 3)**

   Contributions: BB was responsible for conceptualization of the study, data analysis and interpretation, and manuscript writing.
   Institution: University of Guelph, Guelph, ON, Canada
   Supervisor: Prof. Lori Ann Vallis
3. **Becky Breau**, Berit Brandes, Marvin N. Wright, Christoph Buck, Lori Ann Vallis and Mirko Brandes (2021). Association of individual motor abilities and physical activity measures in preschool-aged children. *Journal for the Measurement of Physical*

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Institutions: Leibniz Institute for Prevention Research and Epidemiology -BIPS, Bremen, Germany
Supervisor: Prof. Dr. Wolfgang Ahrens, Dr. Mirko Brandes

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Contributions: BB was responsible for conceptualization of the study, data analysis and interpretation, and manuscript writing.
Institutions: Leibniz Institute for Prevention Research and Epidemiology -BIPS, Bremen, Germany
Supervisor: Prof. Dr. Wolfgang Ahrens, Dr. Mirko Brandes

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LIST OF ABBREVIATIONS

PA – Physical Activity
SED – Sedentary Behaviour
LPA – Light Physical Activity
MVPA – Moderate to Vigorous Physical Activity
TPA – Total Physical Activity
WHO – World Health Organization
FMS – Fundamental Movement Skills
HR – Heart Rate
CNE – Cutpoint Non-Equivalence
SR – Shuttle Run
SLJ – Standing Long Jump
LJ – Lateral Jumping
OLS – One Legged Stand
SAR – Sit and Reach/ Backsaver Sit and Reach
FB – Flamingo Balance test
HGS – Hand Grip Strength
40mS – 40-meter Sprint
20mSRT – 20-meter Shuttle Run Test
OR – Odds Ratio

LIST OF APPENDICES

Chapter 1. Introduction and Brief Review of Literature

1.1 General Introduction

Physical activity (PA) during early childhood (ages 0 – 4 years) has been associated with an abundance of favorable health outcomes including good bone and skeletal heath, improved cardio metabolic health indicators, motor competence and psychosocial health, decreased adiposity (Timmons et al., 2012) and cognitive function (Carson et al., 2016). Higher intensity PA such as moderate-to-vigorous PA (MVPA) as well as total PA (TPA) have consistently shown favourable associations with health outcomes (Carson et al., 2017). Additionally, previous research suggests that PA behaviours can track over time (Jones et al., 2013; Potter et al., 2018) indicating that early childhood is an important window for the development of PA behaviours and an ideal time for targeted lifestyle/health intervention (Collings et al., 2013). Thus, valid, and reliable estimates of free-living movement patterns are needed to test the effectiveness of interventions and examine PA levels in young children.

Numerous methods exist for assessing physical activity and sedentary behaviour levels in children, however obtaining accurate measures of movement behaviours in child populations has proven to be challenging for researchers due to the atypical and sporadic nature of movement patterns in pediatric populations (Bailey et al., 1995). Gold standard techniques for PA assessment such as doubly labeled water and indirect calorimetry are generally not suitable or practical options for pediatric populations due to the their invasive nature, the required expertise and high costs associated with these methods (Sirard & Pate, 2001; Stookey et al., 2011). Several direct observation systems (e.g., Children's activity rating scale (CARS), Activity patterns and energy expenditure (APEE)) are available that allow researchers to obtain information on the type, intensity, context (environmental and social) and location of activity (Pate et al., 2010; Sirard & Pate, 2001). However, use of these systems requires training and time, placing an extensive burden on researchers. Additionally, children may alter their behaviour in the presence of the observer which, in turn, may influence physical activity and sedentary behaviours (Pate et al., 2010). Heart rate (HR) monitors can also be used to measure activity, though they assume a linear relationship between HR and increasing activity intensity (Pate et al., 2010; Sirard & Pate, 2001). Since HR can be influenced by factors such as age, fitness level, and physiological and environmental stressors, the relationship between HR and physical activity is often nonlinear (Pate et al., 2010), suggesting that HR monitors should be used in conjunction with other methods to obtain accurate measures of activity levels in children. Methods such as self and proxy-reported questionnaires rely on accurate responses from responders (Sirard & Pate, 2001). Although these methods allow researchers to efficiently obtain large amounts of data at a low cost, the inherent subjectivity of questionnaires is associated with numerous biases including recall errors, inaccurate responses, and society pressure (Pate et al., 2010; Sallis & Saelens, 2007; Sirard & Pate, 2001). Therefore, these techniques should be interpreted with caution (Sirard & Pate, 2001). Other measurement techniques, such as accelerometry, inertial measurement units and gyroscopes, may present an acceptable compromise between the accuracy of gold standard objective methods (doubly labelled water, indirect calorimetry, direct observation) and the low cost and reduced participant and researcher burdens affiliated with more subjective measures (proxy reported questionnaires).

1.2 Accelerometers

Advances in wearable technology have resulted in numerous devices available to researchers that can effectively quantify sizeable amounts of free-living movement data without largely inconveniencing participants. Although these devices are limited in their ability to measure non-weight bearing activities (i.e. cycling), and cannot provide information on the context of activities (e.g. walking on flat or incline surface), accelerometers can capture information on the duration, intensity and patterns of movement over several days (Pate et al., 2010). Accelerometers have been shown to produce valid and reliable estimates of movement in young children (Costa et al., 2014; De Vries et al., 2009; Pate et al., 2006) during their activities of daily living, thus allowing researchers to capture accurate movement data over long periods of time. Accelerometers measure accelerations of the body segment to which they are attached and depending on the model, can capture movement in one plane (uniaxial) or three planes (triaxial) of movement. Some models output data in the form of raw acceleration signals while others involve various on-board pre-processing steps such as filtering or down sampling and ultimately output data in the form of “activity counts”. Numerous studies have calibrated and validated certain thresholds or cutpoints against criterion measures such as energy expenditure or direct observations to quantify accelerometer counts into estimates of time spent in sedentary behaviour (SED), light PA (LPA) and MVPA for specific age ranges within young children (Butte et al., 2014; Evenson et al., 2008; Pate et al., 2006; Trost et al., 2012). The choice of which cutpoint to use is one of many decisions researchers must reconcile when collecting and analysing accelerometer data from young children. *A priori* decisions such as device make and model, device location, sample frequency must be made before data collection and cannot be altered, while *posteriori* decisions such as epoch length, cutpoint and inclusion criterion are made during processing and can be modified for subsequent analyses. Additional considerations are necessary when using accelerometers in pediatric populations as compliance may rely on cooperation of parents/teachers to ensure that devices are worn correctly and may result in fewer days with valid data. Chapter 2 will discuss these methodological decisions in detail and will highlight the inconsistencies in methodologies used to measure movement patterns in children. The plethora of methodological choices in this area of research has resulted in major methodological inconsistencies, severely hindering comparability across studies (Cain et al., 2013b; Cliff et al., 2009; Migueles et al., 2017). Additionally, the lack of consensus may indicate that the amounts and intensities of movements reported in published research may inadequately represent real-life movements (under or over-estimated). This has important health implications for researchers and clinicians aiming to i) investigate associations between PA and health, ii) conduct research designed to test the effectiveness of interventions, or iii) examine the number of children who meet current guidelines for PA.

1.3 Physical Activity Guidelines

Increased interest in the associations between PA guidelines and health outcomes has resulted following the recent release of new 24-hour movement guidelines for children by several organizations (Tremblay et al., 2016; Tremblay et al., 2017; World

Health Organization, 2010b, 2019) outlined in Figure 1.1A. Specific guidelines have been developed for children aged 1 - 2 years, 3 - 4 years (Tremblay et al., 2017) and 5 – 17 years (Tremblay et al., 2016) which include recommendations for how much sedentary behaviour, light PA (LPA) and moderate-to-vigorous PA (MVPA) children should acquire to maximize health benefits based on multiple systematic reviews (Carson et al., 2017; Chaput et al., 2017b; Kuzik et al., 2017; Poitras et al., 2017). These guidelines recommend that both toddlers (1-2 years) and preschoolers (3-4 years) acquire a minimum of 180 minutes of PA at any intensity per day, and that preschoolers spend at least 60 of those minutes in moderate-to-vigorous physical activity (MVPA) (Tremblay et al., 2017). PA guidelines for children and youth (5 -17 years) recommend a minimum of 60 minutes of MVPA per day (Tremblay et al., 2016). Current research indicates that in Canada, that these PA guidelines are being met by most toddlers (19 months, 99.3%) (Lee et al., 2017), approximately 62% of preschoolers aged 3 - 4 years (Chaput et al., 2017a), and by only one third (36%) of children and youth (5 -17 years) (Roberts et al., 2017) as shown in Figure 1.1 B. Evidence suggests that childhood physical activity levels decrease with age (Dumith et al., 2011; Farooq et al., 2018; Inchley et al., 2020; Rullestad et al., 2021). Some studies suggest that PA levels begin to decline during adolescence (Corder et al., 2015; Dumith et al., 2011), while others suggest that PA is already declining by the time children enter school (Cooper et al., 2015; Farooq et al., 2018). Proposed mechanisms for this decline include reduced sports participation and increased engagement in nonsports activities (Rullestad et al., 2021). Interestingly, research has suggested that this decline may be larger in girls than boys (Corder et al., 2010; Dumith et al., 2011); which may be due to the advanced pubertal maturation of girls compared to boys (Farooq et al., 2018). Additionally, recent results from the health behaviours in school-aged children study of Canadian youth suggest that decreased comfort engaging in activities in front of others, reduced opportunities to participate in sports and a lack of friends and role models who engage in sports contribute to reduced PA levels in girls compared to boys (Craig et al., 2020). Consequently, it has also been suggested that PA levels in girls are lower compared to boys at all ages, but the decline in PA levels from childhood to adolescence is steeper in boys compared to girls (Corder et al., 2015; Inchley et al., 2020).

Investigation into the decline of PA levels throughout childhood and adolescence has important clinical implications as studies have shown that meeting guidelines is favourably associated with adiposity, cardiometabolic disease risk score and fitness in children and youth (Poitras et al., 2016). Investigations of associations between these new guidelines and other health outcomes in children under 5 years are scarce, one study found that adhering to the 24-hour movement guidelines is associated with fewer behavioural problems in 3-year-old children (Carson et al., 2019), and two additional studies found no associations between meeting guidelines and adiposity in toddlers (Lee et al., 2017) or preschoolers (Chaput et al., 2017a). Clearly, additional cross-sectional research is needed to examine the relationship between meeting PA guidelines and other health outcomes during early childhood; longitudinal studies are also needed to determine how these associations may affect health outcomes that might track into later childhood/adolesce.

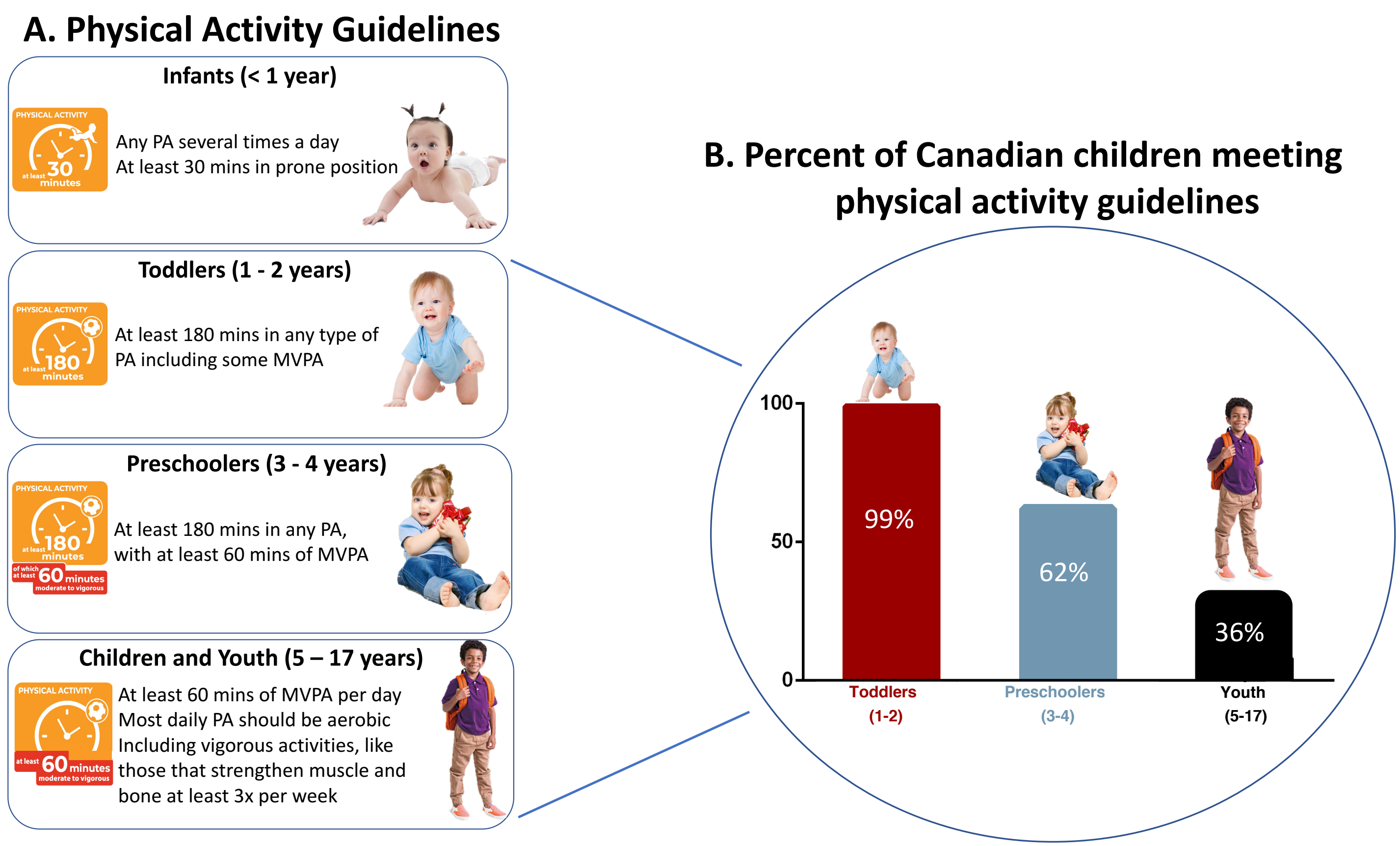


Figure 1.1: Summary of the Canadian[1] and WHO guidelines[2] for PA in children (A) and percentage of Canadian children meeting PA guidelines (B)[3].

[1]Canadian Society for Exercise Physiology PA guidelines for children aged 0 – 4 years (Tremblay et al., 2017) and 5 – 17 years (Tremblay et al., 2016)
[2] World Health Organization PA guidelines for children aged 0 – 4 years (World Health Organization, 2019) and 5 – 17 years (World Health Organization, 2010b)
[3] Percentage of Canadian children aged 1 – 2 years (Lee et al., 2017), 3 – 4 years (Chaput et al., 2017a) and 5 – 17 years (Roberts et al., 2017)

1.4 Cross-sectional and longitudinal associations between PA and health outcomes

Early childhood (< 5 years of age) is a critical time for development during which children learn to move through space and acquire fundamental movement skills (FMS) such as running and jumping (Stodden et al., 2008). As the development of motor competency is a complex and multivariable process that can be heavily influenced by environmental factors (Clark, 1995; Stodden et al., 2008), potential determinants of motor competency such as PA and fitness should be thoroughly examined during these developmental years. The complex relationship between PA, physical fitness and motor competency is outlined in a developmental model proposed by Stodden et al. (2008) which suggests that during early childhood, acquisition of FMS is driven by PA and is mediated by other factors including physical fitness over time. Subsequently, FMS provide the foundation for more complex movements needed for recreational play and sports participation (Gallahue & Ozmun, 2000; Stodden et al., 2008) which can lead to increased fitness levels (Stodden et al., 2008). Accordingly, the model also suggests that during middle to late childhood, motor competency begins to drive PA and therefore, PA during the early years may drive PA during later childhood and adolescence (Stodden et al., 2008).

Previous studies have examined the associations between PA and motor competency (Figueroa & An, 2017; Jones et al., 2020) and between PA and fitness (Fang et al., 2017; Poitras et al., 2016) and have found conflicting results. A lack of consistency in test batteries used to assess motor competency or physical fitness make it difficult to determine associations between PA, motor competency and fitness. For example, test items used to evaluate motor competency have also been used to assess physical fitness (Utesch et al., 2019a; Wrotniak et al., 2006) an issue that is further complicated by the abundance of varying terminologies including “motor ability”, “motor skills”, “motor coordination”, “motor/movement performance”, “movement competence” along with “physical fitness” (Robinson et al., 2015). To clarify, the term motor competency is used to describe the proficiency of any goal-oriented form of human movement involving gross body coordination and control (Coppens et al., 2019; Robinson et al., 2015; Utesch et al., 2019b). Thus, during early childhood, fundamental movement skill (FMS) proficiency is often used to evaluate motor competency (Stodden et al., 2008). In contrast, motor abilities can be defined as the general traits or abilities underlying the performance of FMS (Burton & Miller, 1998); examples of motor abilities include speed, endurance, strength, coordination, balance and flexibility and any combination of these abilities, for example speed strength and strength endurance (Burton & Miller, 1998; Klein et al., 2012). According to Caspersen et al. (1985), physical fitness represents one's ability to execute physical activities requiring aerobic capacity, endurance, strength or flexibility, as such certain motor abilities like flexibility may be considered an indicator of good physical fitness. Owing to its favourable associations with adiposity, cardiovascular disease risk, and skeletal health (Ortega et al., 2008), physical fitness is a key health indicator and should be incorporated in future policies and guidelines.

During the development of the new Canadian guidelines, experts identified cognitive function as a critical indicator of health and subsequent reviews have suggested positive associations between PA and cognitive function (Biddle et al., 2019; Bidzan-Bluma & Lipowska, 2018), and physical fitness and cognitive function (Donnelly et al., 2016). However, due to the lack of longitudinal evidence and high quality randomized controlled trial, reviews also concluded that further research is needed to fully understand the associations between physical activity, fitness, and cognitive function (Poitras et al., 2016). Physiological side effects of physical activities and physical fitness including increased blood flow to the brain, brain neurotransmitter modification as well as improved arousal levels suggest that PA and physical fitness may have additional benefits for cognitive functioning (Sibley & Etnier, 2003), and thus these associations warrant future investigation.

As the proposed nature of the associations between cognition (Biddle et al., 2019), motor competency, physical fitness and physical activity is complex and changes over time (Stodden et al., 2008), it is important that these associations be examined in both cross-sectional and longitudinal manners and that the specific test batteries used to assess cognition, motor competency and physical fitness as well as methods used to assess PA are accurately and thoroughly outlined. An overview of some of the associations between PA and health indicators identified in the systematic reviews conducted by Poitras et al. (2016) and Carson et al. (2017) which helped inform the development of the Canadian PA guidelines are outlined below in Figure 1.2.

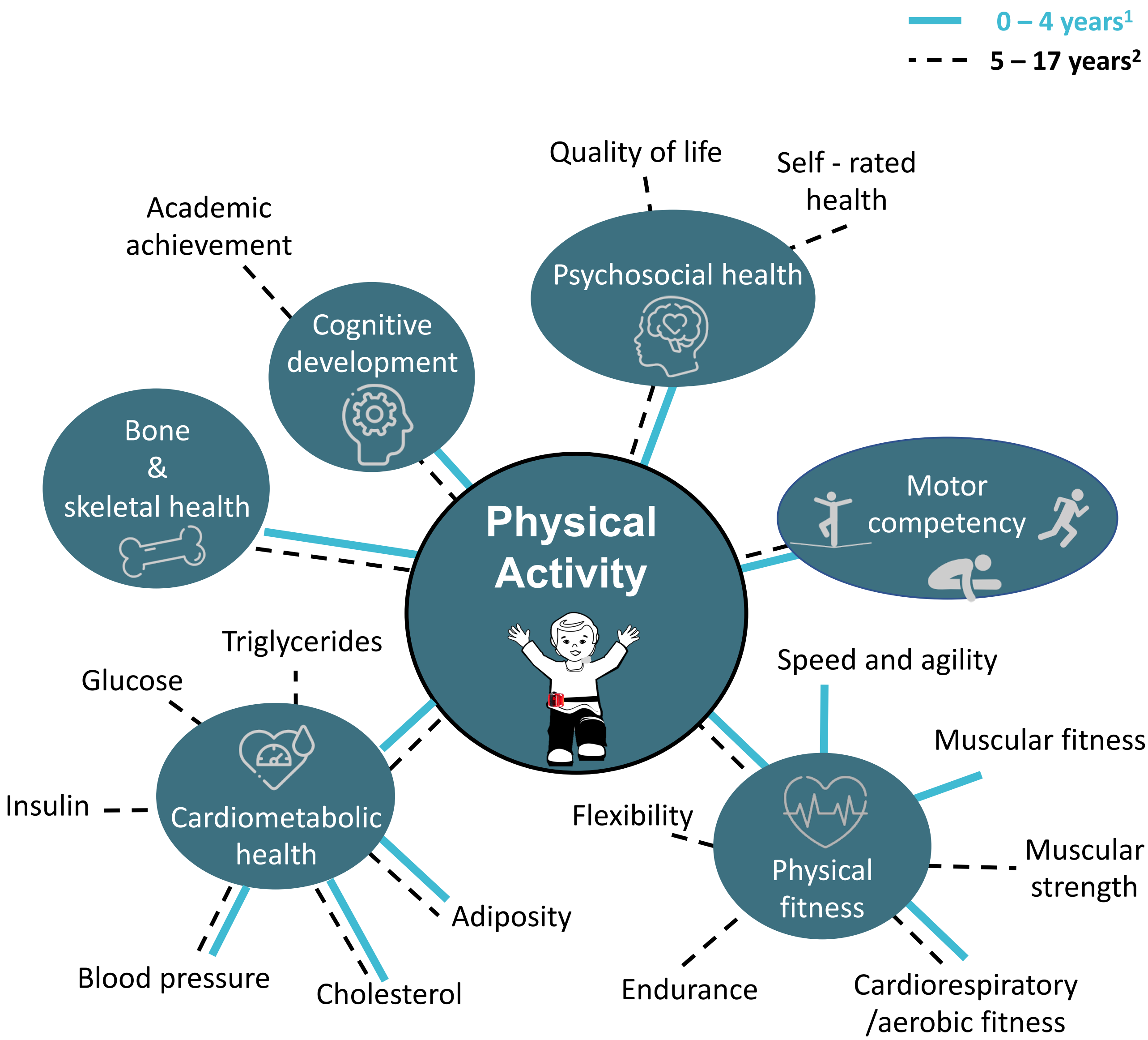


Figure 1.2: Favourable associations between physical activity and other health outcomes as identified in the systematic reviews that informed the development of the Canadian PA guidelines for children aged 0 - 4 years (blue lines) and 5 - 17 years (black dashed lines).

1.5 Summary of Objectives &Hypotheses

It is well known that accelerometers can provide a valid and reliable measure of movement patterns in young children. As outlined in Section 1.2 above, when researchers aim to analyse accelerometer data to quantify movement behaviours in preschool aged children, they are presented with many methodological considerations and must make numerous decisions regarding data collection and processing. As such, many questions pertaining to the most optimal way to collect and analyse data from accelerometers remain. As methodological decisions can impact the outcome metrics acquired from accelerometer data, researchers need to optimize their data collection and processing protocols. Researchers can then use these estimates of the free-living movement behaviours to examine relationships between measures of activity, e.g. does a child meet the current guidelines for physical activity and other health associations.

An aim of this Doctoral dissertation is to gain a better understanding into the methods currently being used to collect and analyse accelerometer data from young children. Following this, a detailed examination into the effects of a specific methodological choice (cut point selection) on outcome measures of physical activity and sedentary behaviour within a preschool aged population was performed. Finally, we aimed to develop a better understanding of how physical activity, specifically meeting physical activity guidelines, is related using two studies; a cross-sectional analysis designed to explore associations between PA and motor ability and a longitudinal data analysis designed to explore associations between physical activity, physical fitness, and cognitive function in males and females from childhood through adolescence.

1.5.1 Study 1

<u>Purpose</u>

The purpose of Study 1 was to comprehensively review the reported published methods used for collecting and processing data acquired from accelerometers worn by preschool aged children. Specifically, methodologies such as accelerometer make and model, accelerometer placement, sample rate, data collection protocol and data processing measures including “non-wear” time definition, description of a “valid day”, epoch duration and cut points used for defining each intensity of movement were examined. This study will provide an overview of the most commonly used methods and will allow researchers to interpret results through a better-informed lens. Additionally, we expect that Study 1 will highlight the poor reporting of these methodologies over the past ten years and will make the case for why more detailed reporting in published papers is needed. In turn, this information may assist researchers in the formation of well thought out experimental designs and will facilitate a more cohesive interpretation of published research findings. This study will also provide insight into how methodologies in this field have changed over the last decade and will suggest areas for future direction within this body of literature.

Objectives

1) This study will provide a comprehensive list of recommended reporting practices for authors to consider when designing studies using accelerometers to investigate free-living movement behaviours in young child populations.

1.5.2 Study 2

Purpose

Study 2 aimed to quantify the effect of applying various cutpoints to data derived from hip-worn accelerometers in a preschool aged population. Specifically, ten different cutpoints were applied to the same data set and the resultant differences in time spent in sedentary behaviour (SB), light physical activity (LPA), moderate-to-vigorous physical activity (MVPA) and total physical activity (TPA) were analysed (Aim 1). A secondary aim was to examine these differences when cutpoints were only applied to the portion of the sample within the *specific* age range for which the cutpoints were originally validated (Aim 2). Finally, we examined how different cutpoints alter the proportion of children meeting Canadian PA guidelines (Aim 3).

Hypotheses

1) We hypothesized that all cutpoints would yield different values for time spent in all movement intensities and that these would all be statistically different from each other. We also expected that the lowest differences would occur in the amounts of time spent in TPA.
2) We hypothesized that a significant difference in time spent in all intensities would still be observed when age specific cut points (from the original validation studies) were applied.
3) We hypothesized that the proportion of children meeting PA guidelines would vary significantly and be dependent on the cutpoint applied.

1.5.3 Study 3

Purpose

The purpose of Study 3 was to evaluate the relationship between individual motor abilities and various objectively assessed PA outcomes within a preschool aged population. Motor ability tests were conducted to assess speed, strength, endurance, coordination, and flexibility. PA measurements included MVPA (mins), TPA (mins), the percentage of total physical activity time spent in moderate to vigorous physical activity (%MVPA of TPA) and whether children are meeting current WHO guidelines for PA.

Hypothesis

1) Time spent in MVPA, TPA, %MVPA of TPA or meeting current PA guidelines recommended by the WHO would be positively associated with all five motor ability tests.

1.5.4 Study 4

Purpose

Study 4 aimed to investigate the longitudinal associations between physical activity, physical fitness, and cognitive function from childhood through adolescence. Specifically, we aimed to examine the association of childhood physical fitness with physical activity and cognitive function during later childhood, early adolescence and how this association differed between males and females before and after puberty.

Hypotheses

1) Children with higher fitness test scores at baseline would have higher amounts of time spent in MVPA and better cognitive function test scores at follow-up several years later
2) Children with higher fitness test scores at baseline would be more likely to meet WHO recommended levels of MVPA at follow-up several years later.
3) Children with higher fitness test scores at baseline would be more likely to meet current WHO recommendations for PA at follow-up several years later.

Chapter 2. Study 1: The use of accelerometers in young children: A methodological scoping review

2.1 Abstract

Accelerometers provide a valid and reliable measurement of movement and allow researchers to examine the associations between free-living movement behaviours and various health indicators. Understanding where methodological inconsistencies exist for the collection and analyses of accelerometer data in young child populations will ensure strong experimental design and assist researchers in the development of solid data analysis plans and proper interpretation of results. To this end, we conducted an extensive scoping review of publications using accelerometers to capture movement behaviours in children aged 6 months to under 6 years and reported on the current methodologies used for data collection and analyses. Specific methodologies that were examined included *a priori* decisions such as device make and model, device placement, sampling frequency and data collection protocol, as well as *posteriori* decisions including definition of non-wear time, inclusion criteria, epoch duration and cutpoints used for classifying accelerometer outputs into specific movement intensities. Five online databases as well as three grey literature databases were searched for peer-reviewed studies as well as conference abstracts, theses and dissertations. Studies were included if they were published in the English language between January 2009 and March 2021. A total of 627 articles were included for descriptive analyses and results showed that the number of articles published in this area has steadily increased over the last eleven years. Of the reviewed articles, 75% used ActiGraph devices, the most common device placement was hip or waist, over 80 percent of articles did not report which sampling frequency was used and seven-day protocols during only waking hours were the most frequently reported. For *posteriori* decisions, 15 second epoch durations and the cutpoints developed by Pate et al. (2006) were the most common. A total of 203 articles did not report which definition of non-wear time was used; when reported, “20 minutes of consecutive zeros” was the most frequently used. Lastly, the most common inclusion criteria were, “greater or equal to 10 hours per day for at least 3 days” for studies conducted in free-living environments and “greater than 50% of the

school day" for studies conducted in preschool or childcare environments. Results demonstrated a major lack of reporting of methods used to analyse accelerometer data from young children. A list of recommended reporting practices was developed to encourage increased reporting of key methodological details for research in this area.

2.2 Introduction

Numerous health benefits have been associated with physical activity (PA), in young children such as improved cardiometabolic health indicators, motor skill development and psychosocial health (Timmons et al., 2012). New PA, sedentary behaviour, and sleep guidelines have been developed to outline the amounts and intensities recommended for specific age groups (Tremblay et al., 2017; World Health Organization, 2019). These guidelines inform parents of how much and what type of movement behaviours their children should be acquiring and allow researchers & clinicians to analyse the impact of reaching/ failing to reach guidelines on other health outcomes. Research suggests that meeting these new guidelines is favourably associated with adiposity, cardiometabolic disease risk score and fitness in children and youth (Poitras et al., 2016), but investigations of associations between these guidelines and other health outcomes in children under 5 years are scarce. One study found that adhering to the 24-hour movement guidelines is associated with fewer behavioural problems in 3-year-old children (Carson et al., 2019), and two additional studies found no associations between meeting guidelines and adiposity in toddlers (Lee et al., 2017) or preschoolers (Chaput et al., 2017a).

To continue to investigate the associations between movement behaviours and health outcomes, as well as the effectiveness of targeted interventions, researchers require valid and reliable estimates of free-living movement in young children which can be captured using accelerometers. Due to the sporadic nature of movement behaviours and patterns in young children (Bailey et al., 1995), structured activities conducted in a lab setting for a set length of time do not accurately represent real-life movement patterns of very young children. Thus, assessment of these movement behaviours in free-living environments is preferred.

Accelerometers provide a valid and reliable estimate of the duration and intensity of movement in young children (Costa et al., 2014; De Vries et al., 2009; Pate et al., 2006) however there are some limitations that accompany the use of these devices. Accelerometers only measure the acceleration of the body segment to which they are attached, for example arm placement of a monitor would not capture movements of the trunk which, in turn, may lead to an underestimation of whole-body PA (Cliff et al., 2009). Furthermore, these devices cannot account for increased energy expenditure associated with carrying a load or activities performed at an incline and also have limited capabilities to measure non-weightbearing activities (i.e. cycling) (Cliff et al., 2009; Pate et al., 2010). However, the relatively low cost, reduced participant and researcher burden and ability to capture data over a long period of time makes accelerometers an ideal device for addressing numerous research questions concerning PA levels in young children. When using these devices, numerous decisions must be made regarding experimental design, protocols, and data processing. Some of the key methodological considerations that must be addressed when collecting and analysing accelerometer data in young children are outlined in **Table 2.1.** These factors include *a priori* decisions which must be made before data collection begins (i.e. accelerometer device make and model, data collection protocol, sampling frequency) in addition to *posteriori* decisions that can be made in advance and/or modified during data processing (i.e. epoch, cutpoint, non-wear time, inclusion criterion). Numerous factors can influence these methodological decisions such as device cost or availability, size of study, availability of funding and research aims. Given the sheer number of factors to consider when using accelerometers to track free-living behaviours in young children, it is understandable that there is lack of methodological consistency in this area of research; for this reason, the reporting of the chosen methodologies has become increasingly important.

For example, decisions such as device placement (Hislop et al., 2016), sampling frequency (Brond & Arvidsson, 2016), epoch duration (Vale et al., 2009) and cutpoint (Janssen et al., 2013; Kahan et al., 2013; van Cauwenberghe, 2011) can impact the interpretation of accelerometer output and subsequent examination of the associations between movement behaviours and health outcomes. Previous reviews have highlighted the inconsistencies in methodologies used to analyse movement behaviours in young children (Bruijns et al., 2020; Cain et al., 2013b; Migueles et al., 2017). However, these reviews have only focused on studies using specific models of ActiGraph devices (Cain et al., 2013b; Migueles et al., 2017) and within the past few years numerous other accelerometers have become available to researchers. Additionally, recent reviews limited the studies to include specific age ranges within preschool aged populations; Bruijns et al. (2020) only examined children under 3 years and Migueles et al. (2017) summarized data for 2 – 5 year olds in their preschoolers group, which may not have accurately captured all of the methods currently being used to collect and analyse accelerometer data in children under the age of 6 years. Lastly, these reviews did not distinguish differences in certain methodologies used in different settings (i.e., free-living versus preschool/childcare settings).

Therefore, the purpose of this paper is to comprehensively review the methods used for i) collecting, and ii) processing and analysing data acquired from accelerometers worn by young children (aged 6 months to under 6 years years) in free-living *and* preschool/childcare environments. Specifically, the reporting of key methodological choices such as accelerometer model, accelerometer placement, data collection protocol and sample rate will be discussed in Part 1, (*a priori* decisions). The selection and implementation of data processing choices including epoch duration, “non-wear” time definition, description of a “valid day” and valid day inclusion criteria as well as cut points used for defining different movement intensities will be discussed in Part 2 (*posteriori* decisions). This scoping review will provide a synopsis of the most reported methods, as well as outline which methods are most often *not* reported and will highlight discrepancies that exist in the current literature. Based on our reading of recent publications in this area, we expect that this scoping review will provide empirical evidence to demonstrate that specific details regarding methodological decisions and processing steps used over the past ten years are often not accurately reported in published papers; we will then aim to provide justification for the need for more detailed reporting.

Table 2.1: Methodological details recorded during data extraction.

A priori methodological decisions	
Accelerometer Make	The manufacturer of the device used. If more than one device was used from different manufacturers, all were recorded. (i.e., ActiGraph, Phillips Respironics, Cambridge Neurotechnology)
Accelerometer Model	The specific model of the accelerometer used. If more than one model was used, all were recorded (i.e. GT1M, GT3X, Actical, Actiwatch -L, ActiHeart)
Device Placement	Where the device was worn for study duration. If more than one location was used, all were recorded (i.e. hip, wrist, ankle, chest)
Sample Frequency	The sample frequency (number of data samples recorded per second) at which the device(s) was set to record. (i.e. 30 Hz, 80 Hz, 100 Hz)
Data Collection Protocol	The total length of time for which participants were asked to wear the device as well as how long the device was to be worn each day. (i.e. 7 days, 5 days, and 24 hours, waking hours only, during school)
Posteriori methodological decisions	
Epoch Duration	The user specified period over which counts/acceleration data are summed. If researchers used one epoch for collection and then aggregated data into another epoch for analysis, the epoch used for analysis was recorded. If more than one epoch was used for analysis, all epochs were recorded. (i.e. 1 sec, 60 sec, 15 sec)
Cutpoint/ Intensity Classification	Thresholds used to classify accelerometer output into intensities. If more than one cutpoint was used, all cutpoints were recorded. (i.e. Pate et al, Evenson et al, Hager et al, Adolph et al etc)
Non-wear Time Definition	The minimum amount of time recording zero movement required for a research team to decide that the device was not worn. Allowance for “non-zero spikes” within this time frame was also recorded. (i.e. 20 minutes of consecutive zero counts, visual inspection)
Inclusion Criteria	Minimum amount of wear time that must be recorded to be deemed a ‘valid’ day along with the minimum number of ‘valid days’ for the child’s data to be included in the analysis. (i.e. minimum of 6 hours per day for at least 3 days)

Additionally, we observed that numerous publications originated from the same project and reported the same or similar methods; we were curious about the influence of these studies on specific methods used in the literature. Therefore, we conducted a frequency sub analysis to examine the influence of large projects with numerous publications on the number of times each epoch duration and cutpoint was reported. We expected that these publications would influence the total number of certain epoch durations and cutpoints that were reported.

This study will also provide insight into how methodologies in this field have changed over the last decade and will provide suggestions for future directions within this body of literature. Finally, we will suggest a comprehensive list of 'recommended' reporting practices for authors using accelerometers to investigate free-living physical activity and sedentary behaviour in young child populations.

2.3 Methods

2.3.1 Study design

The present review focuses on the methodologies used to obtain and analyse accelerometer data from populations of children between the ages of 6 months and under 6 years. Specific methodological details that were reviewed include device make and model, device placement, sampling frequency, data collection protocol (i.e., how long was the device worn), epoch, non-wear time definition, definition of a valid day (i.e., amount of wear time needed to include a day in analyses), inclusion criteria (i.e., number of valid days required for participant to be included in analysis) and cutpoint or intensity classification (see **Table 2.1** for details). Additionally, a *frequency sub analysis* was conducted on projects/studies that resulted in multiple publications but were all based on the same initial data set; this allowed us to investigate common experimental practices for research projects that generate multiple publications. The protocol for this review, which contained inclusion and exclusion criteria and analytical methods, were determined in advance, and archived in the University of Guelph Library online repository (http://hdl.handle.net/10214/16867). The overall approach of this scoping review closely followed the PRISMA guidelines for systematic reviews and meta-analyses.

2.3.2 Search Strategy

For this review, we conducted electronic searches using the following databases: Medline (via OvidSP), CINAHL, PsycINFO, Web of Science and Global Health CABI. A search of grey literature was conducted through Google Scholar (first 20 pages of search results from Google Scholar), ProQuest conference papers and proceedings, ProQuest dissertations and Open Access Theses and Dissertations. We consulted with a research librarian at the University of Guelph to build search strategies that were adapted to the syntax of all databases and subject headings were used when appropriate. Search strategies were designed to capture studies using all types of accelerometers in child populations to measure outcomes such as physical activity or sedentary behaviour (**Full search strategies are available in Appendix 1**). Our first round of searches was conducted on August 16th, 2019 and was limited to studies published in the English language between 2009 and 2019. Due to delays caused by the COVID-19 pandemic, another search was conducted on March 22nd, 2021, to capture any additional publications between August 16th, 2019, and March 22nd, 2021. The second search was conducted using the same search strategies in the five previously searched databases: (Medline (via OvidSP), CINAHL, PsycINFO, Web of Science and Global Health CABI), grey literature searches were not conducted during the second search.

2.3.3 Inclusion/Exclusion Criteria

All original studies (cross-sectional, longitudinal or intervention studies) using any accelerometer model with children between the ages of 6 months and under 6 years old for any duration of time were eligible for inclusion. As studies investigating children often include a sample of a wide age range, thus a strict review process was followed with details below:

1) Children aged 5 and 6 years were included but studies that included children aged 5-7 years, 5-8 years, etc. were not included
2) Any study including an age range that started at 4 years of age or below (i.e., 4-18 years, 4-12 years, etc) was included
3) Studies on infants where the maximum age was 6 months were excluded

The rationale for the first criteria listed above was that in studies investigating children 5 and 6 years old, half of the age range falls within our included age range (6 months to under 6 years), whereas the majority of the age range in studies with samples of children aged 5-7 and older falls outside of the age range in our study. The second criteria listed above was chosen to ensure that this review captured the methodologies used in studies looking at young children, we felt that if the methods were used on children as young as 4 years old, then these methods should be included in our study. Conversely, the third criterion was chosen to limit the number of studies that examined infants from inclusion in our review.

Protocols, reviews, editorials, or abstracts with minimal details (i.e., less than three of the methodological details outlined below) were excluded as well as studies conducted in a lab environment with structured activities (i.e., calibration and/or validation studies). Studies conducted on children with conditions that could impact mobility (i.e., Cerebral Palsy, Downs Syndrome, Cystic Fibrosis, Spina Bifida, Diabetes, Autism, cancer, malnutrition) were only included if a control group of typically developing children were included in the sample. As a main focus of this article was to report on the processing steps used for analysing accelerometer data, studies that used ActivPal devices or pedometers (i.e., Fitbits™) were excluded. The ActivPal device output is limited to reports of “movement postures” and the output of pedometers is limited to the number of steps. Additionally, most of the processing techniques are proprietary for ActivPal and Fitbit devices (i.e., user cannot modify device settings). Lastly, studies that reported using an accelerometer but only reported on the measurement of sleep metrics were excluded.

Two authors (BB and H-CA) independently reviewed the title and abstracts of articles obtained from the searches. Studies that were excluded by both reviewers were excluded, all remained studies passed to full-text article screening and any discrepancies in this stage were resolved by a third reviewer (LAV).

2.3.4 Data Extraction

The specific methodological details that were recorded during data extraction are outlined in **Table 2.1**. These details were categorized into *a priori* details (i.e., decisions that must be made prior to data collection and cannot be altered for processing) and *posteriori* decisions (i.e., decisions that are made during data analysis and can be altered). *A priori* (Part 1) details included accelerometer make and model, device placement, sample frequency and data collection protocol. *Posteriori* (Part 2) decisions included epoch, cutpoint or intensity classification, non-wear time definition, software used for data processing and inclusion criteria (i.e. definition of a valid day and minimum number of valid days required).

2.3.5 Frequency Sub Analysis

It is typical to examine a variety of research questions using data from the same project; observed associations between variables of interest may then be published separately. This approach is financially feasible and optimizes the contributions of study participants. As such, numerous publications may result from the same project/original data set, using the same or similar methods. We were curious about the number of times multiple publications stem from the same original project that have reported on measuring children's movement behaviours with accelerometers. It is possible that certain processing techniques are considered more 'popular' or 'commonly used' since there are more papers citing these methods in the published literature however it should be recognized that these publications all come from the same original data set. Subsequently, a separate analysis was conducted for two important methodological details (epoch, and cutpoint/intensity threshold) to investigate the influence that multiple publications stemming from a single data set have on these methods used in this field of research. These two details were chosen as epoch duration was found to be one of the most frequently reported details in a recent review (Migueles et al., 2017), and cutpoints have been shown to have a great influence on accelerometer output (Costa et al., 2014; Janssen et al., 2013; Kahan et al., 2013) which in turn is often used by researchers and clinicians to determine if children are meeting PA guidelines (van Cauwenberghe, 2011).

For this analysis, we identified which publications stemmed from the same project and identified projects with multiple publications. Publications were then grouped together and identified as having used the same data set. Next, a rank order was applied to these studies based on the number of publications associated with each study. The top 25% where then included in the frequency sub analysis.

2.4 Results

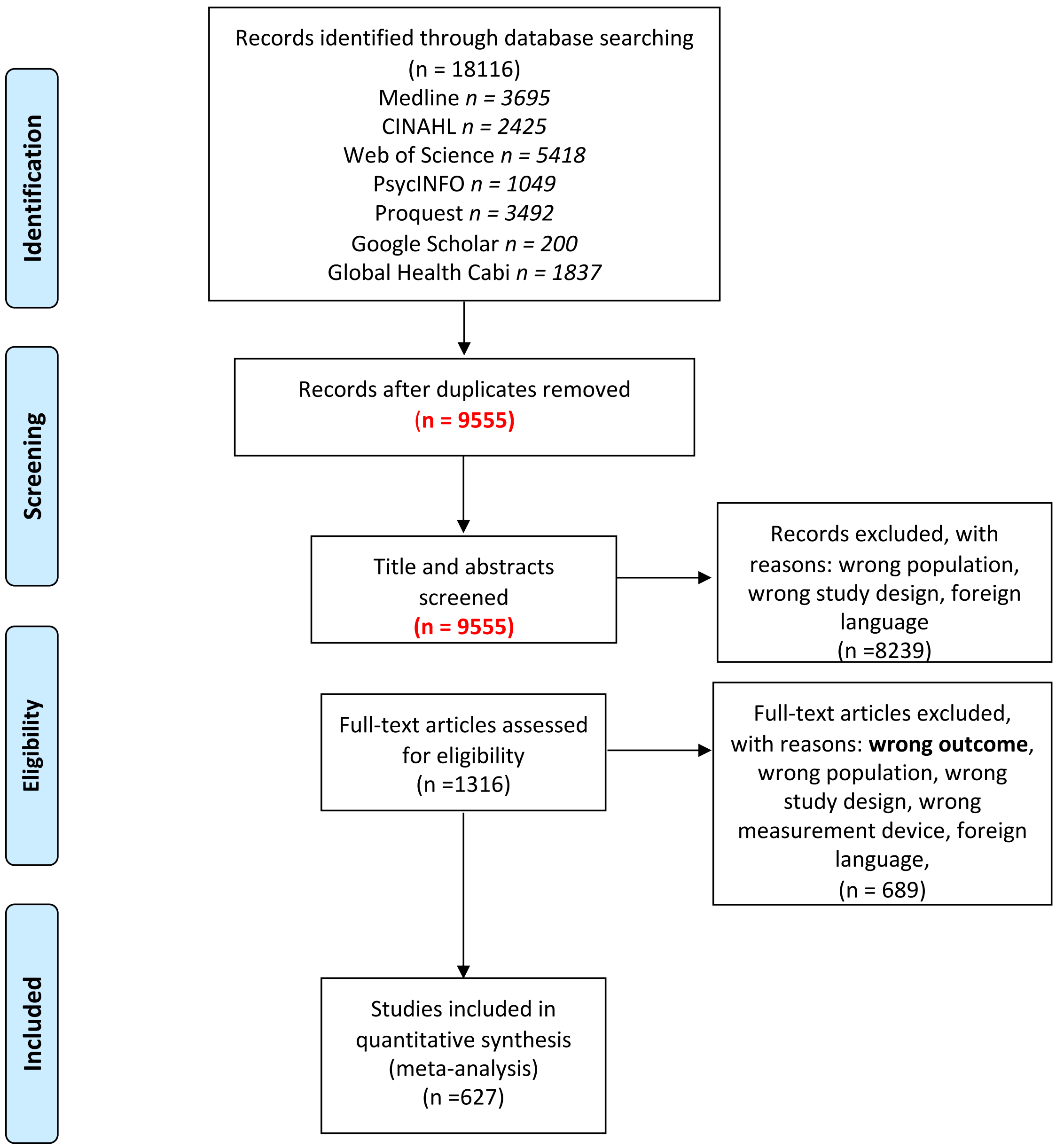
2.4.1 All individual studies

Figure 2.1 illustrates results from the searches performed. After duplicates were removed, 9555 articles were identified; 8239 articles were excluded following title and abstract screening (BB and H-CA). An additional 689 articles did not meet inclusion/exclusion criteria after reading the full text and were excluded, leaving a total of 627 articles included in our subsequent descriptive analyses. A full Bibliography of all included articles is available in **Appendix 2.**

2.4.2 Frequency sub analysis

This analysis identified that 368 publications (out of a total of 627 studies included in this Scoping Review) reported on data from 84 original studies. When the rank order was applied to these 84 studies (number of publications associated with each study) we determined that 21 original studies produced 194 individual publications. This represented 25% of the 84 ranked ordered studies, and 31% of all 627 studies included in this Scoping review. These publications were chosen for the frequency sub analysis.

Fig 2.1 PRISMA 2009 Flow Diagram



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit www.prisma-statement.org.

Figure 2.1: PRISMA diagram for the identification, screening, eligibility, and inclusion of studies.

2.4.3 Publication year

Figure 2.2 shows the number of publications included in this review that were reported each year from 2009 -2021. Recall that our second search (conducted due to COVID delays) was conducted in March 2021; this resulted in an additional 103 studies for our scoping review with 84 published in 2020 and 19 published in the early months of 2021 (January to March 22, 2021).

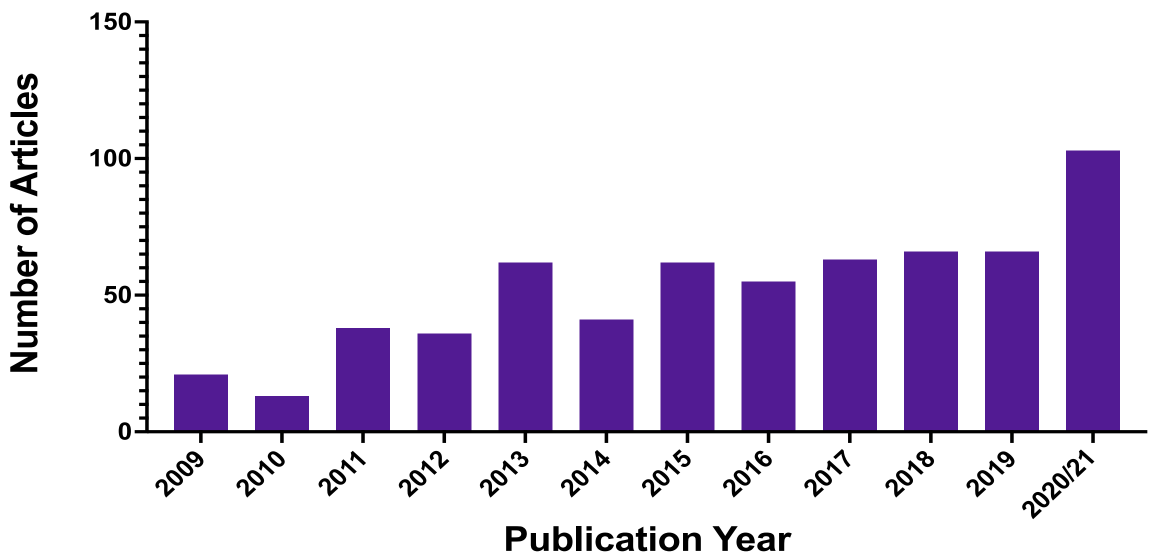


Figure 2.2: Number of articles analysing accelerometer data in young children published between January 2009 and March 2021 out of the 627 articles included in this review.

<u>Part 1: *A priori* decisions</u>

2.4.4 Device Make and Model

The number of studies that reported using each accelerometer make and model are shown in **Figure 2.3**. For studies that reported using two accelerometers (n=12), both devices were counted and added to the total number of devices reported (627 + 12 = 639). A total of 480 studies reported using an ActiGraph device, making it the most common brand of accelerometer reported in this review (75%). Multiple studies reported using more than one model of the ActiGraph device, as such all models mentioned were counted and a total of 557 ActiGraph models where reported. Of the numerous models offered by ActiGraph the GT1M (n = 156) and GT3X+ (n = 125) devices were the most used models. Other frequently used devices were manufactured by Phillips Respironics (previously Mini Mitter, n = 81) and Cambridge Neurotechnology (n=18). The most popular model from Phillips Respironics was the Actical (n=81), while the ActiHeart was the most reported model produced by Cambridge Neurotechnology (n = 18). Details regarding the device make and model were not explicitly reported in 11 studies. Within the studies using ActiGraph devices, 6 did not report the specific model, 7 reported just that ‘a uniaxial model was used’, and 6 studies reported using models that do not exist (reporting error).

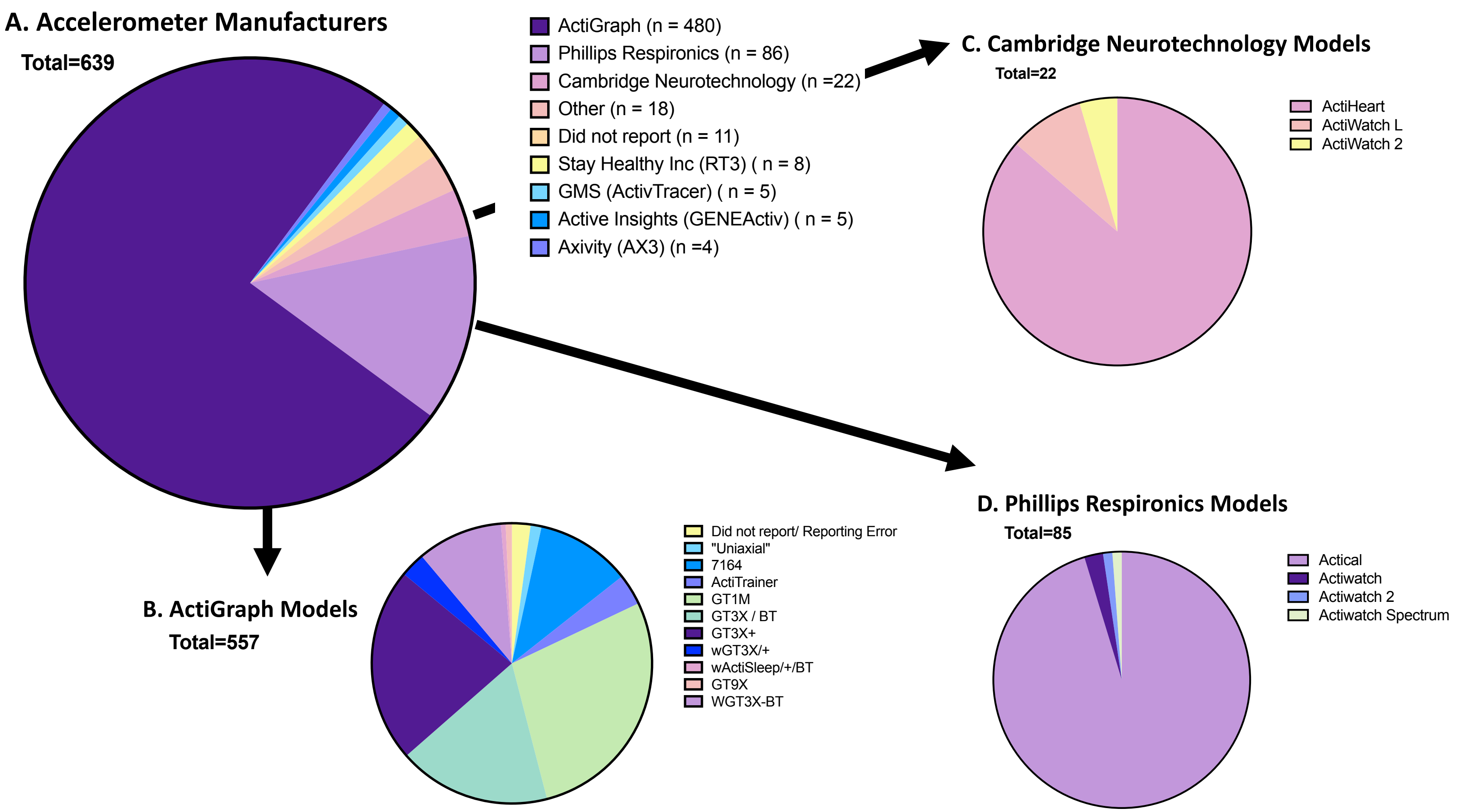


Figure 2.3: Number of articles that reported each (A) Accelerometer manufacturer, and the device model for the three most reported manufacturers: (B) ActiGraph, (C) Cambridge Neurotechnology, and (D) Phillips Respironics.

*Note that 12 studies reported using two accelerometers (total of 639), and for the ActiGraph models, numerous studies reporting using multiple models of AcitGraph devices, making the total out of 557.

2.4.5 Device Placement

Figure 2.4 displays details regarding the specific device placements reported by studies included in the review. For studies that reported using accelerometers at two locations (n=12), both locations were counted and added to the total number of device placements reported (627 + 12 = 639). The most frequently reported location was the hip/waist (N=459 out of 639; 72%). Of these, a total of 147 studies reported that the device was worn on the "hip or waist"; 10 additional studies reported the device was worn on the left hip and 302 studies reported that the device was worn on the right hip. The second most frequent device placement location was the wrist (n = 49), followed by the ankle (n=21), the chest (n =15), then back (10) and finally the thigh (n =1). A total of 84 studies did not report device placement.

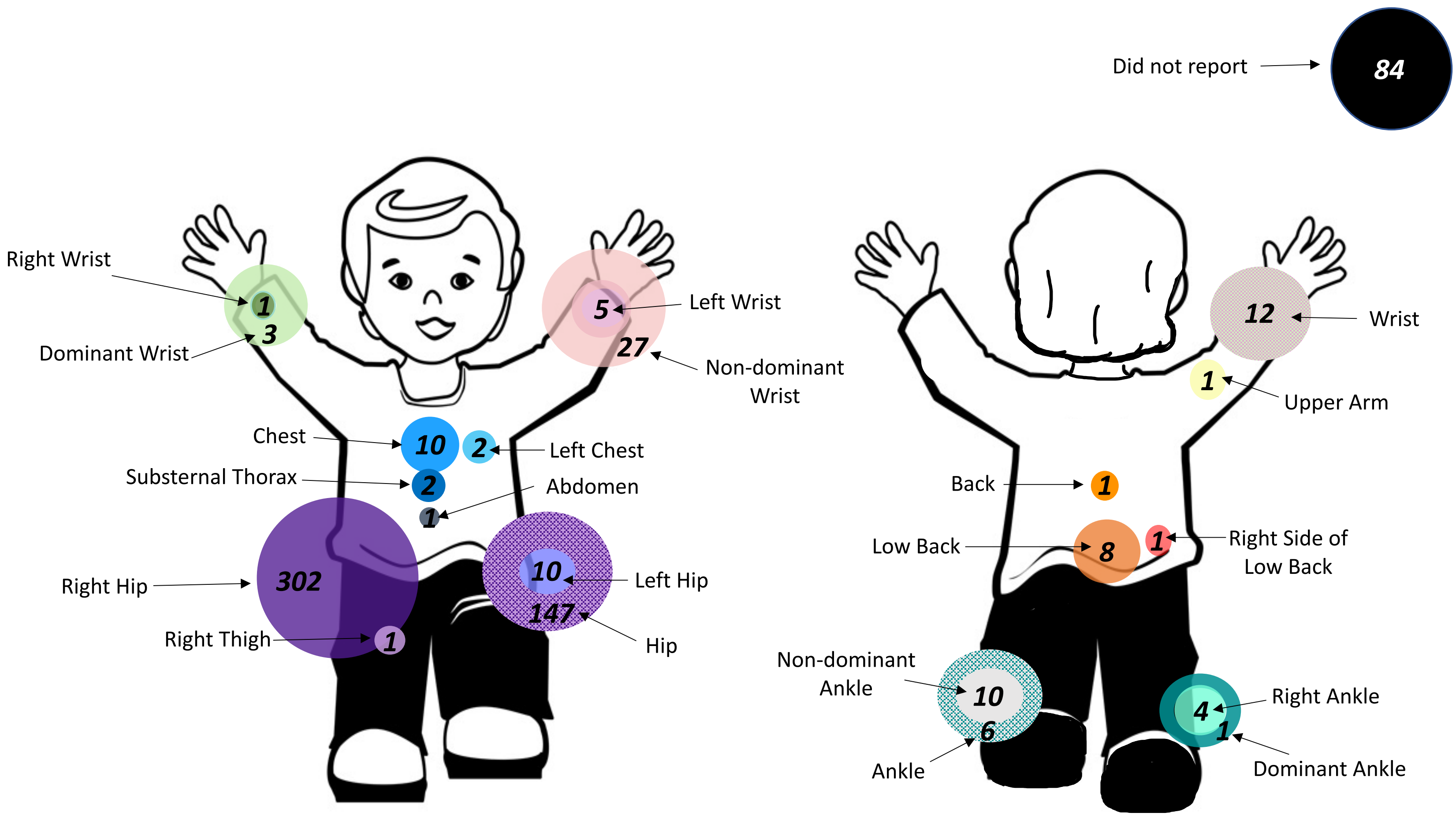


Figure 2.4: Device placement for all articles included in the review.

**Note that 12 studies reported using 2 device placements for a total of 639 device placements represented in the above figure.*

2.4.6 Sample Frequency

The studies that reported sample rate (n = 119) are shown in **Figure 2.5,** note that one study reported using two different sample frequencies and both are reported here (n =120)**.** A sample frequency of 30 Hz was the most common (n = 75), followed by 60 Hz (n = 12) and 100 Hz (n = 10). Sample frequency was not reported in 508 or 81% of studies included in this review.

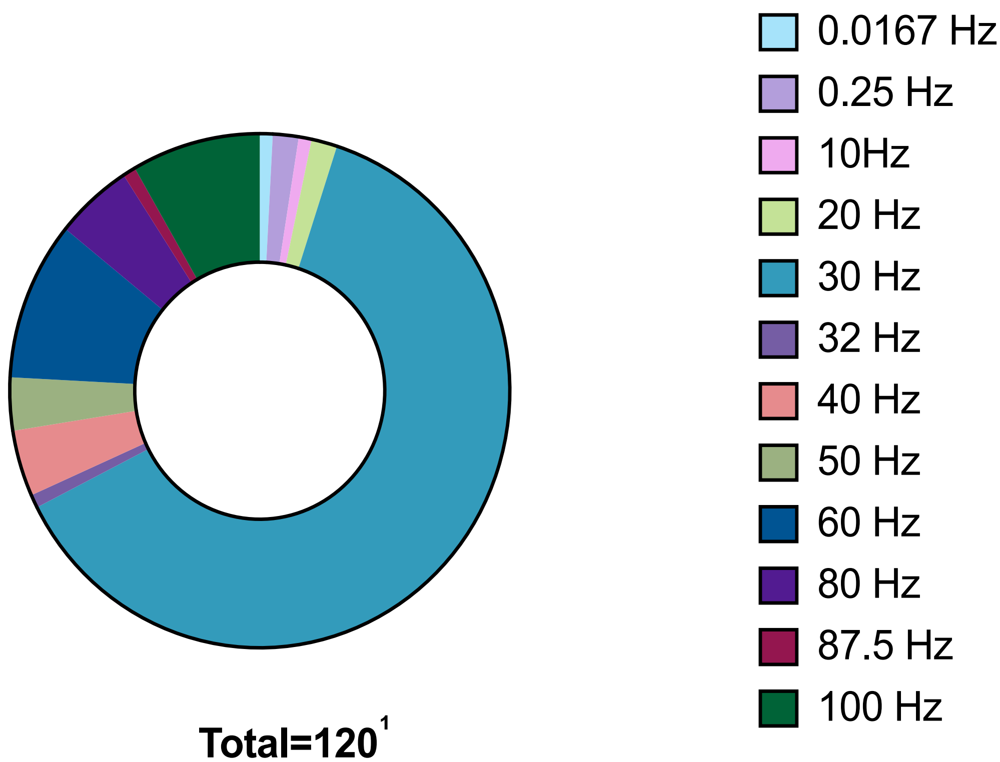


Figure 2.5: Number of articles that reported using each Sample Frequency[1].

[1]One study reported using two sample frequencies and 508 studies did not report which sample frequency was used.

**Note that some older devices only have one sample frequency setting available, however these were still counted as "did not report" since the sample frequency was not explicitly reported in the published article.*

2.4.7 Data Collection Protocol

Detailed results regarding data collection protocols followed, i.e., the time children were requested to wear the device and the length of time each day (24 hours/day, waking hours only, preschool hours etc) are presented in **Table 2.2.** Please note that for protocols conducted at preschool/childcare centers some studies cited the specific hours during which the device was worn (i.e., 9 am -2 pm), but the majority did not provide specific times, therefore all studies conducted at preschool/childcare centers were reported as “preschool hours” in this scoping review.

Data collection protocols of 7 days were the most frequently reported (n = 283), of which 117 were for 24 hours per day, 124 were during “waking hours only”, 5 were during preschool hours and 37 did not report context concerning how children were asked to wear the device each day. Regarding when the devices were to be worn during data collection, studies that collected data during waking hours only were the most common (n=265), followed by 24 hours/day (n=169) and lastly at preschool/childcare (n=85). A total of 113 studies did not provide context regarding when the device was worn during the data collecting protocol.

Table 2.2: Data collection protocols reported from all studies included in this review

[1] Articles that cited a protocol of “1 week during preschool” were counted under 5 days

Data collection Protocol	Total	Context details			
		24 hrs/day	Waking hours only	Preschool/Childcare	Did not report
Did not report	35	1	15	-	19
1 day	20	5	-	-	15
2 days	14	1	6	6	1
3 days	38	4	16	10	8
4 days	33	3	20	9	1
5 days[1]	100	19	22	42	17
6 days	25	9	8	1	7
7 days/ 1 week	283	117	124	5	37
8 days	34	2	29	-	3
9 days	2	-	2	-	-
10 days	3	-	-	2	1
11 days	1	-	1	-	-
14 days/ 2 weeks	21	1	16	1	3
16 days	1	1	-	-	-
28 days	2	2	-	-	-
1 – 4 days	1	-	-	1	-
4 – 5 days	2	-	2	-	-
5 – 7 days	1	1	-	-	-
6 – 7 days	1	1	-	-	-
6 – 8 days	2	2	-	-	-
7 – 8 days	1	-	1	-	-
7 – 9 days	1	-	-	-	1
8 – 10 days	3	-	3	-	-
One Structured Period[2]	8	-	-	8	-
Total[3]	632	169	265	85	113

[2] Articles that cited data collection protocols at preschools such as; recess, one physical education class, 1 hour session at school, 1 play period. Times ranged from 30 – 104 mins

[3] 5 studies used two data collection protocols (one baseline, one follow-up, or combined data from studies with different data collection protocols

Part 2*: Posteriori* decisions

2.4.8 Epoch duration

The epoch durations stated in the studies included in the full analysis as well as the frequency sub analysis portion of this review as are displayed in **Figure 2.6.** A total of 613 studies reported using 1 epoch duration, 13 studies reported using 2 different epoch durations and 1 study reported using 3 different epoch durations, for a total of 642 epoch durations cited from the 627 articles in this scoping review. Of the 642 reported epoch durations, a total of 51 studies did not report which epoch duration was selected; the most frequently used epoch duration was 15 seconds (n = 329), followed by 60 seconds (n = 130) and 5 seconds (n =56). The remaining 76 citations reported using epochs between 1 second and 2 minutes or reported using no epochs at all (i.e., raw data analyses). Of the total number of times 15 second epoch durations were cited (n =329), the frequency sub analysis revealed that 108 of those citations came from 14 of the project studies with multiple publications. Subsequently, of the total number of times 60 second epoch durations were reported (n =130), the frequency sub analysis revealed that 59 of those citations were from 11 large project studies.

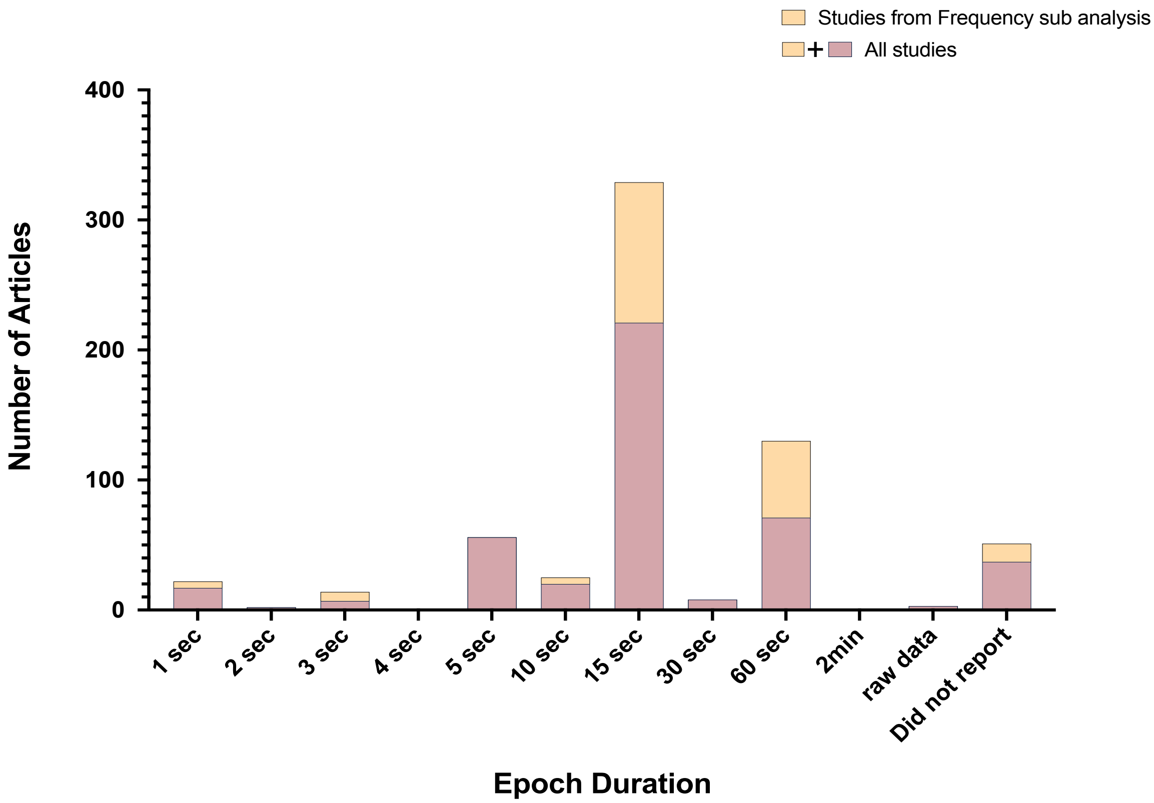


Figure 2.6: Number of times each Epoch duration was cited. Papers from the Frequency sub analysis are in orange; all other studies are depicted in pink. Total number epoch durations cited from studies reviewed (N=642, some studies used multiple epoch durations) is on the y-axis and is a sum total of the frequency sub analysis and other studies (i.e. pink + orange bars).

2.4.9 Cutpoints/ PA intensity classification

Many studies combine multiple published cutpoints (i.e., one cut point for sedentary behaviour and another for MVPA) or test the difference in outcome following the application of multiple cutpoints. Given this, the total number of cutpoints reported in studies using ActiGraph devices was 587; 114 for studies using Phillips Respironics devices and 21 studies using Cambridge Neurotechnology devices. The top 5 most reported cutpoints in studies using ActiGraph devices are shown in **Figure 2.7A**; the top 7 most reported cutpoints in studies using Phillips Respironics devices are illustrated in **Figure 2.7B,** and the total number of cutpoints cited in studies using Cambridge

Neurotechnology devices are illustrated in **Figure 2.7C**. A total of 44 studies did not report how different intensities were classified or did not quantify accelerometer output into different intensities and just reported counts per minute or raw acceleration as physical activity. The most reported cutpoints in studies using ActiGraph devices were those calibrated by Pate et al. (2006) (n = 157), followed by the Evenson et al. (2008) cutpoints (n =110), the Trost et al. (2012) (n = 55), the Butte et al. (2014) cutpoints (n=40) and the Sirard et al. (2005) cutpoints (n=40). The most reported cutpoints in studies using Phillips Respironics devices were those calibrated by Pfeiffer et al. (2006) (n = 33), followed by Adolph et al (n =18), Wong et al (n = 14), Evenson et al (n=7), Hager et al (n = 6), Colley et al (n = 5) and Puyau et al (n = 4). A total of 18 studies using Phillips Respironics devices did not report which cutpoint was used. In studies using Cambridge technology devices, the cutpoints that were reported included, De Bock et al. (2010) (n =4), Pate et al. (2006) (n = 4), Ridgeway et al (n =1), Corder et al (n = 1) and Sundberg et al (n =1), while a total of 10 studies did not report a cutpoint.

In the frequency sub analysis, 18 of the main studies used ActiGraph devices (**Figure 2.7A**) and 3 of the main studies used Phillips Respironics devices (**Figure 2.7B**). In studies using ActiGraph devices, this frequency sub analysis revealed that out of all cutpoints reported in this review (n = 587), 216 were cited in publications that stemmed from 18 original studies. In studies using Philips Respironics devices, the frequency sub analysis revealed that out of all cutpoints reported in this review (n = 587), 30 were cited in publications that stemmed from 3 original studies.

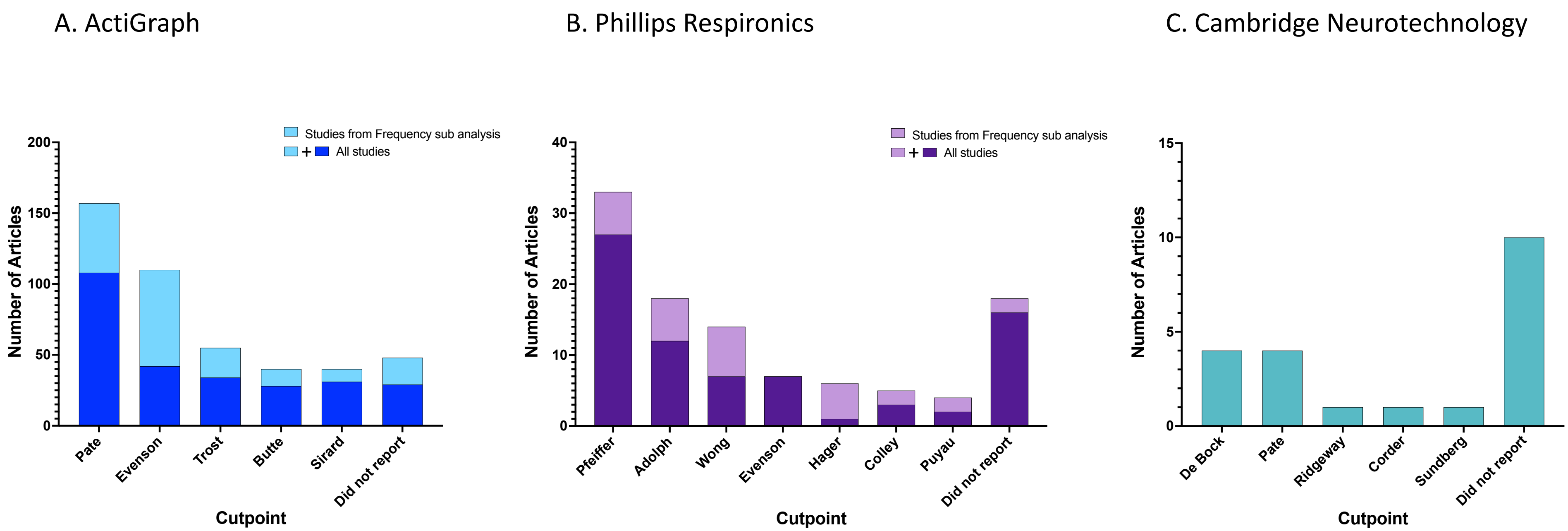


Figure 2.7: Number of times each cutpoint was referenced in articles using devices from A) ActiGraph, B) Phillips Respironics and C) Cambridge Neurotechnology. Papers from the Frequency sub analysis are in A) light blue and B) light purple, no studies from the frequency sub analysis used Cambridge Neurotechnology devices; all other studies are depicted in A) dark blue, B) dark purple and C) teal. The number of cutpoints cited from studies using ActiGraph devices/Phillips Respironics devices/Cambridge Neurotechnology devices is on the y-axis and is a sum total of the frequency sub analysis and other studies (i.e. A) dark blue + light blue, B) dark purple + light purple).

**Note that many articles cited multiple cutpoints, hence the number of cutpoints reported totalled 587 (ActiGraph devices), 114 (Phillips Respironics) and 21 (Cambridge Neurotechnology). The 5 most frequently reported cutpoints in studies using ActiGraph devices and the 7 most reported cutpoints in studies using Phillips Respironics devices are shown. All cutpoints cited in studies using Cambridge Neurotechnology devices are shown.*

2.4.10 Non-wear time definition

The criteria used to identify periods of non-wear time are listed in **Figure 2.8.** A total of 203 studies did not report how non-wear time was defined, while the most frequently described definition of non-wear time was, “20 minutes of consecutive zero counts”, which was reported in 150 publications, followed by “60 minutes of consecutive zeros” in 120 publications and “10 minutes of consecutive zeros” in 55 publications. Non-wear time was identified and removed using visual inspection in conjunction with parent reported log sheet times in 21 studies. The remaining 78 studies reported other definitions of non-wear time as detailed in **Figure 2.8**.

2.4.11 Inclusion criteria

Full details regarding the number of times each definition of a valid day, as well as the number of valid days required for inclusion in analysis, are reported in **Table 2.3** for studies conducted in free living environments and in **Table 2.4** for studies conducted in a preschool or childcare setting. Note that some studies reported multiple different valid day definitions or inclusion criteria, thus the total number of valid days and an inclusion criterion reported was captured in 643 protocols.

In free-living studies, the most common valid day definition was “greater than or equal to 10 hours of valid wear time” and the most common number of required valid days for inclusion was 3 days. In studies conducted in preschool or childcare environments, “greater than or equal to 3 hours of valid wear time was the most common valid day definition and 3 days was also the most common number of required days for studies in this setting.

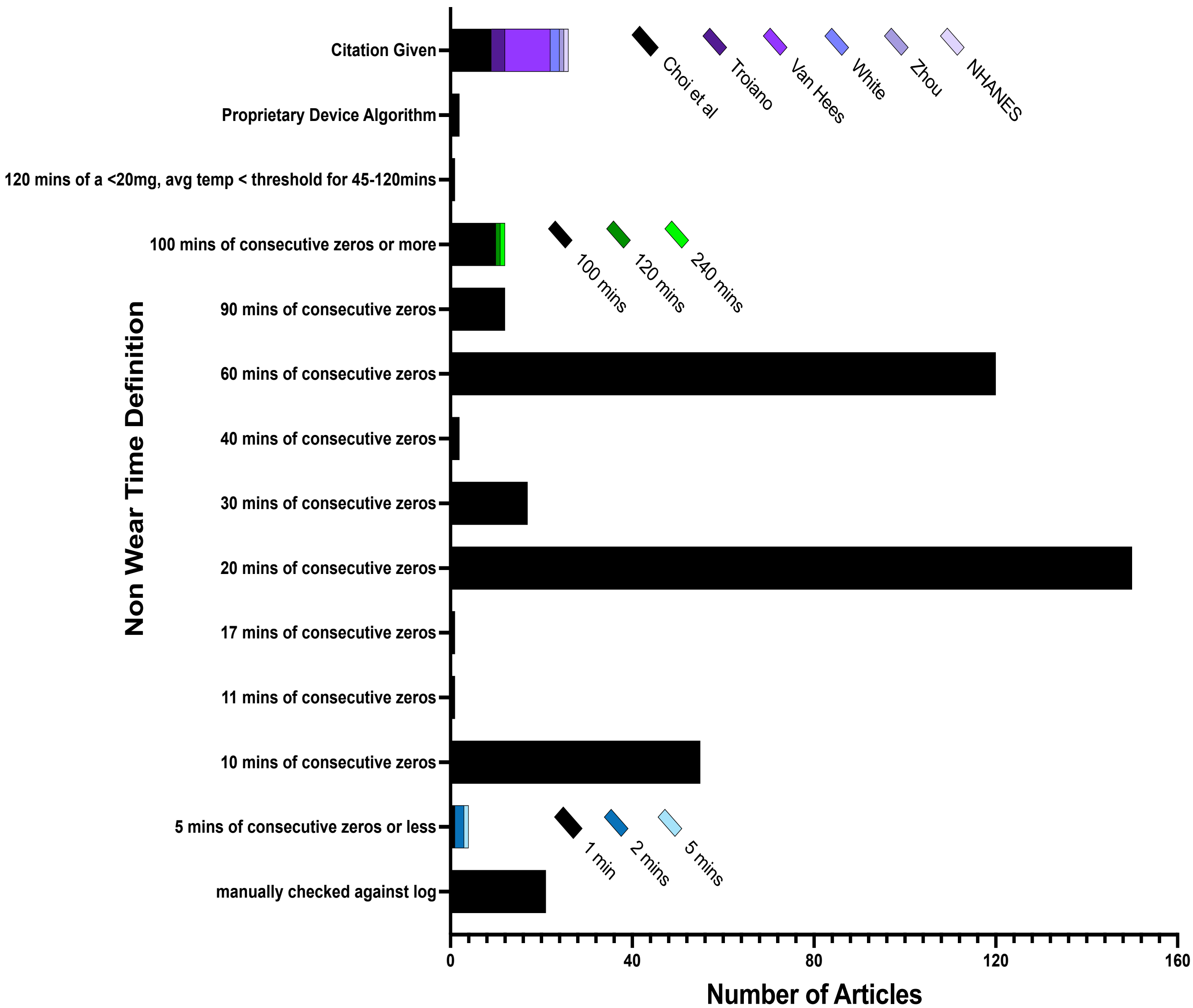


Figure 2.8: Number of times each Non-Wear Time definition was reported.

[1] No specific definition of non-wear time was given but a citation of an algorithm was reported

**Note that 203 articles did not report any definition for Non-Wear Time (not shown)*

Table 2.3: Number of times each valid day definition and number of valid days required for inclusion was reported for studies conducted in free-living environments

"Valid day" definition	Total	Number of valid days required for inclusion							
		1	2	3	4	5	6	7	N/A
Did not report	133	-	-	-	-	1	-	1	131
≥ 1 hr	2	1	-	1	-	-	-	-	-
≥ 2 hrs	1	-	-	1	-	-	-	-	-
≥ 3 hrs	5	-	-	1	-	-	-	-	1
≥ 4 hrs	16	4	6	2	1	2	-	-	1
≥ 5 hrs	32	3	2	17	7	1	-	-	2
≥ 6 hrs	87	5	4	41	32	-	2	-	2
≥ 7 hrs	15	-	-	3	12	-	-	-	-
≥ 8 hrs	86	6	9	36	27	1	-	1	6
≥ 8 hrs (WD), ≥ 7 hrs (WE)	1	-	-	-	1	-	-	-	-
≥ 9 hrs	6	-	-	2	2	1	-	-	1
≥ 10 hrs	114	11	3	48	28	1	2	3	18
≥ 10 hrs (WD), ≥ 8 hrs (WE)	1	-	-	1	-	-	-	-	-
≥ 15 hrs	1	-	-	1	-	-	-	-	-
≥ 16 hrs	5	-	-	3	-	-	1	-	1
≥ 18 hrs	1	-	-	-	-	-	-	-	-
≥ 19 hrs	2	-	-	-	-	-	-	-	-
≥ 20 hrs	4	-	-	1	1	.	.	1	1
≥ 24 hrs	10	6	2	1	1	-	-	-	-
≥ 400 mins	4	-	2	2	-	-	-	-	-
≥ 500 mins	16	2	1	7	4	-	-	-	2
≥ 1000 mins	2	-	-	-	2	-	-	-	-
≥ 3 hrs, ≤ 18 hrs	1	-	-	-	-	-	-	1	-
≥ 4 hrs, ≤ 18 hrs	1	-	1	-	-	-	-	-	-
≥ 5 hrs, ≤ 18 hrs	1	-	-	1	-	-	-	-	-
≥ 6 hrs, ≤ 18 hrs	2	-	-	-	-	-	2	-	-
≥ 8 hrs, ≤ 18 hrs	1	-	-	-	-	-	-	-	1
≥ 8 hrs, ≤ 20 hrs	1	-	-	1	-	-	-	-	-
≥ 3 hrs – 10 hrs	2	1	-	-	1	-	-	-	-
5 – 17 hrs	1	-	-	1	-	-	-	-	-
6 – 18 hrs	1	-	1	-	-	-	-	-	-
10 – 20 hrs	1	-	-	-	1	-	-	-	-
≥50% of waking hrs	3	-	-	-	3	-	-	-	-
≥50% of waking hrs, ≤ 18 hrs	1	-	-	-	1	-	-	-	-
≥60% of waking hrs	1	-	-	1	-	-	-	-	-
≥75% of mins in any hr	1	-	-	-	1	-	-	-	-
≥80% of measurement day	1	-	-	-	1	-	-	-	-
80/70 rule[1]	9	-	-	9	-	-	-	-	-
Days with >40% non WT[2]	1	-	-	-	-	-	-	-	1
Days with >50% non WT[2]	1	-	-	-	-	-	-	-	1
Days with > 2 hours non WT[2]	3	-	-	3	-	-	-	-	-
Days with <80 cpm (average)[2]	2	2	-	-	-	-	-	-	-
Days with 3 x 20mins of non WT[2]	2	-	2	-	-	-	-	-	-
Total[3]	581	41	33	184	126	10	7	7	172

WD = Weekday, WE = Weekend Day, WT = Wear Time, N/A = did not report [1]80% of total time during which 70% of sample wore the accelerometer, [2]Studies listed exclusion criteria instead of inclusion criteria for valid days, [3] Note that some studies reported using two or three inclusion criteria in their study

Table 2.4: Number of times each valid day definition and the number of valid days required for inclusion was reported for studies conducted in preschool or childcare environments

WE = Weekend Days

		Number of valid days required for inclusion							
"Valid day" definition	**Total**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**Did not report**
≥ 30 mins	1	-	-	1	-	-	-	-	-
≥ 1 hour	3	-	1	2	-	-	-	-	-
≥ 2 hours	4	1	-	-	3	-	-	-	-
≥ 2.5 hours	4	-	-	2	2	-	-	-	-
≥ 3 hours	12	5	2	3	-	-	-	-	2
≥ 4 hours	2	-	1	-	-	-	-	-	1
≥ 4 hours after school	2	-	-	2	-	-	-	-	-
≥ 5 hours	2	-	-	-	2	-	-	-	-
≥ 6 hours	2	-	2	-	-	-	-	-	-
≥ 7.5 hours[1]	1	-	1	-	-	-	-	-	-
≥ 8 hours	2	-	-	-	1	1	-	-	-
≥50% of school day	10	2	1	7	-	-	-	-	-
≥75% of time at childcare	7	2	4	1	-	-	-	-	-
Entire classroom day	7	3	2	-	-	1	-	-	1
≥50% of WT after school	1	-	-	-	1	-	-	-	-
≥50% of WT after school, ≥ 8 hours on WE	1	-	-	-	1	-	-	-	-
≥ 4 hrs, ≥ 1 hr after school and ≥ 5 hrs on WE	1	-	-	1	-	-	-	-	-
Total[2]	62	13	14	19	10	2	0	0	4

[1]Note that this study required 1 childcare day and 1 home care day

[2] Note that some studies reported using two or three inclusion criteria in their study

2.5 Discussion

2.5.1 Summary of evidence

Accelerometers provide valid and reliable measures of free-living movement behaviours in young children (Butte et al., 2014; De Vries et al., 2009; Pate et al., 2006) and can provide valuable information to those wishing to examine associations between movement behaviours and other health outcomes. As shown by the sheer number of publications included in this review, the use of accelerometers in young children has markedly increased over the past 10 years (see **Figure 2.2**). Other measures of physical activity and sedentary behaviour, such as parental reports or questionnaires have shown weak to no correlations with accelerometer-derived measures of PA in young children (Sarker, 2015; Small, 2013) thus accelerometers provide a feasible alternative method of capturing free living information regarding both the duration and intensity of movement in child populations.

Although numerous devices are readily available to researchers, the number of methodological decisions and processing steps required to obtain the desired output are numerous. With little to no consensus in the literature (Cain et al., 2013b; Migueles et al., 2017), the methodological inconsistencies in this area of research are quite apparent. Additionally, the lack of reporting specific details regarding data collection and processing techniques makes it difficult to fully interpret results across studies (Migueles et al., 2017). Thus, we aimed to present reporting practices of key details on common methodologies that have been used over the past 10 years to collect and analyse accelerometer data from young children. As a result of the lack of details reported found in this review, a practical list of recommended reporting practices has been developed (see list at end of Discussion). It is our intention to help limit confusion in the literature and inform researchers of key parameters to consider when developing their study protocols and data analysis plans.

A priori decisions

2.5.2 Device Make and Model

Results from this review demonstrate the ActiGraph accelerometers are the most used devices in studies investigating movement behaviours in young children, as 75%

of the studies included in this review used ActiGraph accelerometers. Popularity of the ActiGraph devices has been shown previously in adults (Wijndaele et al., 2015); past reviews have also reported on the prevalence of ActiGraph devices in use for the measurement of movement behaviours in children aged 0 to 5 years (Cain et al., 2013b; Migueles et al., 2017). To our knowledge, this is the first review to confirm that the ActiGraph accelerometer is the most frequently used device in children between the ages of 6 months and 6 years. With rapid technological advancements and growing interest in quantifying movement behaviour in young children, it is important that scoping reviews are conducted every few years to report on key methodological changes within the published literature.

An important finding from this review pertains to our observations about the specific model of accelerometer used. Our data extraction revealed that 18 different models of ActiGraph devices were reported; unfortunately, 6 articles reported models that did not exist (reporting error), and an additional 13 studies did not report the specific model that was used. Due to the variability in technical specifications such as number of axes, sample rate, on board filtering, calibration processes and epoch capabilities between models, it is essential that researchers report the specific make and model of the device used in their study.

2.5.3 Device Placement

Accelerometers measure accelerations of the body segment to which they are attached, therefore it is crucial to report where devices were worn. Our review showed a wide variety of device locations being used to capture movement in young children, specifically 21 different locations were reported, and 84 studies did not report where the device was worn. The most commonly device placement was the hip with 459 articles reporting this location, 147 of which reported the “hip”, 302 reported “right hip” and 10 reported ‘left hip”. Hip placement has been the logical preference of researchers to capture accelerations that are representative of whole-body movement. Furthermore, this placement is recommended by the ActiGraph cooperation, suggesting that devices should be worn on the hip as this is closest to the center of mass and will produce the most accurate data (ActiGraph, 2019). Placement of the device on the wrist was the second most reported location (n = 48), with 12 studies reporting “wrist”, 5 reported “left wrist”, 1 reported “right wrist”, 3 reported “dominant wrist” and 27 reported “non dominant wrist”. A recent shift towards wrist mounted accelerometers has occurred with the change in protocol for the National Health and Nutrition Examination Survey (NHANES) in the United States as wrist placement was chosen to increase participant compliance and account for arm movement that may not be captured with hip-worn accelerometers (NHANES, 2011; Rowlands et al., 2014). Research has shown that wrist placement overestimates measures of PA while, hip placement overestimates measures of sedentary behaviours in young children (Hislop et al., 2016). Differences in accelerometer outputs caused by device placement make it crucial for investigators to report the device placement chosen in their study. Given the wide variety of device placements reported in this review, future work should continue to investigate the comparability between outputs obtained from devices worn at different locations in young children.

2.5.4 Sample Frequency

Our review demonstrates the immediate need for increased reporting of sample frequency. Over 80% of the studies reviewed did not report which sample frequency was used in their study. While some older device models only have one sample frequency setting, this methodological detail should always be reported given its’ importance to the interpretation of human movement data (Brond & Arvidsson, 2016). To date, little is known about how sample frequency specifically affects accelerometer output acquired from young children, however Brond and Arvidsson (2016) showed that sample rate does affect output in ActiGraph accelerometers worn by young adults. Reporting sample frequency is becoming more crucial with the shift in focus towards machine learning and activity recognition algorithms in this field of research. Newer device models allow for higher sample frequencies over multiple days, thus in line with previous recommendations (Migueles et al., 2017), we recommend that the highest sample frequency possible (i.e., 90 - 100Hz) be used to capture sporadic movement of children and to also help decipher differences in low intensity movements.

2.5.5 Data Collection Protocol

Results showed a wide variety of data collection protocols being used and further highlighted the variability of contexts during which movement behaviours can be captured by accelerometers (i.e., preschool childcare/waking hours/24 hours). The most common wear period reported was for 7 days, 24 hours/day. Many large-scale studies have adopted this protocol (Colley et al., 2019; Katzmarzyk et al., 2013; NHANES, 2011), and wear compliance has been shown to be higher in studies using a 24 hour versus waking hours only protocols (Tudor-Locke et al., 2015). Additionally, with the recent development of 24-hour movement guidelines for physical activity, sedentary behaviour, and sleep in young children (Tremblay et al., 2017; World Health Organization, 2019), the use of 24-hour protocols is likely to increase. Therefore, researchers are urged to continue reporting the details regarding data collection protocols that were used, and it is further recommended that if 24-hour protocols are used, methods regarding the processing steps taken to remove period of sleep should be accurately reported. Additionally, all details of the chosen measurement protocol (i.e. number of measurement days, repeated measurements, time and place of measurement) should be accurately reported and justified for the proposed research question.

Posteriori decisions

2.5.6 Epoch duration

The release of newer models of accelerometers has facilitated increased user selection choice for epoch duration. Our results found that 15 second epochs were the most reported (n = 329), followed by 60 second epochs (n = 130) and 5 second epochs (n = 56). Vale et al. (2009) demonstrated that 5 second epochs resulted in significantly higher amounts of MVPA compared to 60 second epochs in preschool-aged children and Nettlefold et al. (2016) concluded that measures of MVPA, LPA and sedentary behaviour differed with the use of 15 and 60 second epochs in children 8 – 11 years old. However, both studies used early models of the ActiGraph device (uniaxial models 7164 and GT1M), therefore newer research is needed to investigate the differences in the output of next generation (i.e., triaxial) accelerometers when different epochs are used. Shorter epochs have been suggested as they facilitate the capture of the sporadic movements of children in this age group (Jimmy et al., 2013; Kahan et al., 2013), and we also recommend that shorter epoch durations be used (i.e. 1 second, 5 second and 15 second), and also would like to encourage researchers to always report the epoch duration used in their analyses. Additionally, if separate epochs were used for downloading and analysing accelerometer data (i.e., downloaded in 5 second epochs then reintegrated into 15 second epochs), these details should be reported and accompanied by details regarding how reintegration was completed.

Results from the frequency sub analysis revealed that studies with numerous publications have a large impact on the representation of certain epoch durations within the literature. For example, 15 second epoch duration was reported a total of 329 times from all studies included in this review, 108 of these citations came from 14 studies using the same methods/data set. If each of these studies were only counted once instead of counting all the publications stemming from these original projects, then the number of times that 15 seconds epochs were used would decrease to 235. Given the impact that epoch duration can have on movement data, we would encourage researchers to carefully consider which epoch duration is most appropriate for their research questions and study population and not simply choose the “most popular” epoch duration.

2.5.7 Cutpoints/ PA intensity classification

Our results found an abundance of different cutpoints cited for quantifying accelerometer data from children into specific intensities (SED, LPA, MVPA). Of studies using the ActiGraph devices, 41 different cutpoints were reported. Of these, the Pate et al. (2006) cutpoints were the most frequently reported and surprisingly 44 studies did not report which cutpoint was used. For studies using Phillips Respironics, 14 different cutpoints were cited, of which the Pfeiffer et al. (2006) cutpoints were the most cited; 18 studies did not report which cutpoint was used. Only 5 different cutpoints were reported in studies using Cambridge Neurotechnology devices, of which the De Bock et al. (2010) and the Pate et al. (2006) cutpoints were the most reported. It is important that the original cutpoint calibration/validation study is referenced when using a specific cutpoint to ensure readers have easy access to that information. Reporting practices concerning cutpoints should involve reporting values for all thresholds used in the study and the values reported should align with the epoch used in the study. For example, if 5 sec epochs were used, counts should be reported as 30 counts/5 sec. Additionally, the software that was used to apply cutpoints should be mentioned as certain software programs have specific processing techniques. For example when applying cutpoints within the ActiLife software to non-60 second epoch files, each epoch is multiplied by the value required to equal 60 seconds, as all cutpoints are based on 60 second epochs within the software (https://actigraphcorp.force.com/support/s/article/How-are-Cut-Points-Calculated). Thus, if 15 second epochs were used, all counts obtained in each 15 second period would be multiplied by 4, and counts based on 60 second epochs would then be applied to the data. As open-source software and coding techniques become more frequently used in this field of research, it is increasingly important that the details regarding the choice of cutpoint used, and how they are applied to the data, are thoroughly reported.

Results from the frequency sub analysis revealed that studies with numerous publications have a large impact on the representation of specific cutpoints within the literature. For example, the Evenson et al. (2008) cutpoints were cited a total of 110 times out of 627 studies included in this review; 68 of these citations came from 12 studies using the same methods/data set. If each of these studies were only counted once instead of all the publications stemming from the same original project, then the number of times the Evenson et al. (2008) cutpoints were cited would decrease to 54 citations. Although this did not impact the ranking of the most popular cutpoints, it does show that numerous publications stemming from a limited number of original studies have a large representation in the literature. Subsequently, we reiterate our recommendation that researchers should choose the cutpoints or methods for classifying accelerometer data into different movement behaviours based on what is most appropriate for their research questions and not based on what is most frequently reported in the literature.

The severe lack of consistency in use of cutpoints is concerning as numerous studies have shown that the application of different cutpoints can significantly impact the amount of time spent in different intensities quantified from accelerometer data (Hislop et al., 2012; Janssen et al., 2013; van Cauwenberghe, 2011) and can, in turn, impact reports on the number of children meeting PA guidelines (van Cauwenberghe, 2011). Clearly, accurate reporting of cut points used and how they were applied to the data will provide clear and consistent interpretation of accelerometer results.

2.5.8 Non-wear time definition

Results from our review indicated that numerous definitions are being used to determine non-wear times. Specifically, 18 different non-wear time definitions were reported, of which the most reported was “20 minutes of consecutive zero counts” (n = 150), followed closely by “60 minutes of consecutive zero counts” (n = 120). Additionally, a total of 203 studies did not report how non-wear time was defined in their analysis. Reviews by both Cain et al. (2013b) and Migueles et al. (2017) also found that definitions of non-wear time was often not reported. This is crucial as non-wear time misclassified as wear time could result in an overestimation of sedentary behaviour, therefore researchers need to know how non-wear time was defined.

2.5.9 Inclusion criteria

Our scoping review demonstrated that there is a wide variety of definitions of a valid day as well as the number of days required for inclusion in analyses. Of the studies conducted in a free-living environment, 42 different definitions of a valid day were reported as well as a range of 1 to 7 valid days required to meet inclusion criteria. Additionally, 133 studies did not report their definition of a valid day and 131 of those studies did not report how many valid days were needed. The most frequently used inclusion criteria for free-living studies was “greater than or equal to 10 hours per day for a minimum of 3 days” (n = 48), followed closely by “greater than or equal to 6 hours per day for a minimum of 3 days” (n = 41). Penpraze et al. (2006) found that an inclusion criterion of 7 days, 10 hours per day resulted in the highest reliability and increased days of monitoring for increased hours resulted in increased reliability up to 10 days in a sample of young children. However, good reliability (>70%) was found for monitoring periods between 3 and 10 hours as long as 5 or more days was required (Penpraze et al., 2006). Additionally, those authors concluded that increased reliability was *more* dependent on the number of valid days than the number of hours in a valid day (Penpraze et al., 2006). More recently, Byun et al. (2015) found that 6 – 9 days of monitoring were needed to achieve an Interclass Correlation coefficient (ICC) of greater than or equal to 0.8 when investigating sedentary behaviour in preschool aged children. Consequently, that study showed that only 2 -4 days of monitoring was required to achieve the same ICC when measuring sedentary behaviour in a school setting (Byun et al., 2015).

A unique component of our review is the distinction of inclusion criteria reported by studies conducted in a free-living environment and in a preschool or childcare environment. For studies conducted in a preschool/childcare environment, 17 different definitions of a valid day were reported with inclusion criteria ranging from 1 to 5 valid days. All studies conducting in this unique environment reported the valid day definition and only 4 studies did not report how many days were required for inclusion.

As the required inclusion criteria can affect the reliability of PA and sedentary behaviour estimates, it is important that reported inclusion criteria are detailed, which will also better inform other researchers when designing their analysis plans.

2.5.10 Strengths/Limitations

There are certain limitations of this review that should be noted. The first of which is the exclusion of studies using certain devices such as pedometers, ActivPal and commercial devices (i.e. Fit Bits). These devices were excluded as they provide outputs in the form of steps or time spent in certain postures and very little is known about the processing steps in these devices as most algorithms are proprietary. Given the sheer volume of articles included in this review, further separate reviews may be needed for those devices. The wide age range of studies included in this review renders making specific recommendations for children outside of our age range of interest (between 6 months and under 6 years) inappropriate. Additionally, we did not report on methods used to removed sleep periods from accelerometers as this was poorly reported in many articles.

The strengths of this review include the large number of studies included a thorough overview of the literature published in the last 10 years within this area of research has been captured. The inclusion of multiple devices and models provides more information to a broader group of researchers. Additionally, the frequency sub analysis conducted in this review highlighted the effect that large studies with multiple publications can have on the literature in this field of study.

2.5.11 Recommended reporting practices

The most obvious result from this review is the large volume of methodological details that were not reported in published (peer-reviewed) research. This observation was also made in a recent review conducted by Migueles et al. (2017), and our findings confirm that the lack of reporting important details has not improved over the past few years. These results formed the basis for the following list of recommend details tobe reported in any study using accelerometers quantifying movement behaviours in young children:

1. **We recommend that the make and model of the device used be reported.**

   Rationale: Technological advances and increasing popularity have led to multiple generations of devices produced from the same manufactures. With each new model, upgrades in technical specifications and processing techniques compromise the comparability with previous models, meaning the appropriate model must be reported to allow researchers to make appropriate interpretations.

2. **We recommend that the device placement be reported.**

   Rationale: Newer accelerometers can be worn on multiple locations of the body, which in turn will impact how the data acquired should be processed. Thus, the device placement should be accurately reported, with any necessary details (left, right, dominant, non-dominant, etc.)

3. **We recommend that Sample Frequency be reported.**

   Rationale: As certain devices allow users to select a sample rate from numerous options, we strongly recommend that sample frequency be reported. As sample frequency has been shown to affect count outputs from ActiGraph accelerometers (Brond & Arvidsson, 2016), and as research using raw acceleration data becomes increasingly popular thus converging engineering, biomechanics and health science fields, this methodological detail should always be reported.

4. **We recommend that if using a cutpoint, the original calibration study should be cited and the actual cutpoint values used be reported.**

   Rationale: With a plethora of cutpoint options available, it is essential that the original validation study be cited. Additionally, as researchers apply cutpoints to various epochs, the specific cutpoint values applied to the chosen epoch data should be reported. This also highlights the importance of reporting the software used during analysis as certain software programs; for example, Actigraph may complete this process differently than manually coded programs.

5. **We recommend that researchers report the definition of non-wear time used to identify and remove periods of time when the device was not worn.**

   Rationale: Multiple algorithms have been developed to detect periods of non-wear however, to our knowledge, no such algorithm has been developed and validated for use in young children. As researchers have used a wide variety of non-wear time definitions and reporting specific details, including citations of specific algorithms is strongly advised.

2.6 Conclusions

There is a large abundance of studies using accelerometers to capture and analyse movement data from young children. Collectively, researchers in this area of study need to enhance reporting practices to increase transparency and allow scientists to be better informed when making methodological decisions for analysing children's accelerometer data.

Chapter 3. Study 2 ActiGraph cutpoints impact physical activity and sedentary behaviour outcomes in young children

3.1 Abstract

Background: The purpose of this study was to examine the effect of ten cutpoints on the amount of time children spend in different intensities and on the proportion of children meeting physical activity (PA) guidelines.

Methods: 262 children (3.6 ± 1.4 years, 126 male) wore ActiGraph wGT3X-BT accelerometers on their right hip for 7 days, 24 hrs/day. Ten cutpoints were applied using ActiLife software within age-appropriate categories. Resulting times in sedentary behaviour, light PA, moderate-to-vigorous PA, and total PA, were compared using repeated measures ANOVAs. The proportion of children meeting age-appropriate PA guidelines based on each cutpoint was also assessed using Cochran's q tests.

Results: Significant differences in time spent in each intensity were found across all cutpoints except for time in sedentary behaviour and total PA for three comparisons (Trost vs Butte VA; Pate vs Puyau; and Costa VA vs Evenson) and for time in MVPA for four comparisons (Trost vs Pate; Trost vs Pate & Pfeiffer; Pate vs Pate & Pfeiffer and Van Cauwenberghe vs Evenson). When examined within age-appropriate groups, all cutpoints resulted in significant differences across all intensities and in the number of children meeting PA guidelines.

Conclusion: Choice of cutpoint applied to data from young children significantly affects times calculated for different movement intensities which in turn impacts the proportion of children meeting guidelines. Thus, comparisons of movement intensities should not be made across studies using different cutpoints.

3.2 Introduction

During early childhood, physical activity (PA) provides numerous health benefits including improved cardiometabolic health indicators and decreased adiposity (Timmons et al., 2012). Despite these benefits, children continue to spend most of their time engaging in sedentary behaviour (SED) (Reilly, 2010). In Canada, specific PA guidelines have been developed for children 1 – 2-years, 3 – 4-years (Tremblay et al., 2017), and children 5 – 17-years-old (Tremblay et al., 2016) to encourage increased PA and reduced SED time. To determine if children are meeting guidelines, an objective measurement of free-living PA is needed.

Accelerometers are wearable devices that measure accelerations of the body part to which they are attached with minimal inconvenience. Data can be downloaded as 'activity counts', summed over a user specified period (epoch) and divided into intensities of movement such as SED, light PA (LPA), moderate-to-vigorous PA (MVPA) and total PA (TPA) by applying cutpoints derived from calibration studies using criterion measures (i.e. VO2 or direct observation) within specific age ranges (Butte et al., 2014; Costa et al., 2014; Evenson et al., 2008; Freedson et al., 2005; Pate et al., 2006; Pulsford et al., 2011; Puyau et al., 2002; Sirard et al., 2005; Trost et al., 2012). Technological advances coupled with rising interest in childhood obesity has resulted in a plethora of research in this area causing large methodological inconsistencies and an overwhelming number of choices researchers must face when analysing accelerometer data (Burchartz et al., 2020; Cliff et al., 2009; Migueles et al., 2017).

The term 'cutpoint non-equivalence' has emerged in the literature and defines the issue caused by the extensive variety of cutpoints available for classifying accelerometer data into different intensities, which severely hinders comparability across studies (Bornstein et al., 2011). This is a prevalent issue among studies using ActiGraph accelerometers as they are the most frequently used devices (Migueles et al., 2017) with a large number of available cutpoints (Butte et al., 2014; Costa et al., 2014; Evenson et al., 2008; Freedson et al., 2005; Pate et al., 2006; Pfeiffer et al., 2009; Pulsford et al., 2011; Puyau et al., 2002; van Cauwenberghe, 2011). Previous studies using ActiGraph devices have shown that the use of different cutpoints yields differences in the amount of time in MVPA, LPA and SED (Costa et al., 2014; Leeger-

Aschmann et al., 2019; van Cauwenberghe, 2011) and that this can affect the number of children meeting PA guidelines (van Cauwenberghe, 2011). At present, few studies have examined the effect of various cutpoints on *all movement intensities* including total PA (TPA). Additionally, in the literature, cutpoints developed using a specific age range are commonly applied to accelerometer data acquired from children outside of this age range (Gutierrez-Hervas et al., 2020; Määttä et al., 2020). Little is known about how this practice may impact the calculations of PA intensities and in turn how this impacts our ability to use accelerometer data to determine if a child is meeting PA recommendations for their age group.

Therefore, we aimed to examine differences in minutes spent in SED, LPA, MVPA and TPA when ten different cutpoints were applied to data derived from hip-worn accelerometers in 1.5 – 6-year-old children (Aim 1). A secondary aim was to examine these differences when cutpoints were only applied to the portion of the sample within the specific age range for which the cutpoints were originally validated (Aim 2). Finally, we examined how different cutpoints alter the proportion of children meeting Canadian PA guidelines (Aim 3). For Aim 1, we hypothesized that all cutpoints would produce significant differences in time spent in all intensities and that the lowest differences would occur in the amounts of time spent in TPA. For Aim 2, we hypothesized that a significant difference in time spent in all intensities would be observed within all age groups. Lastly, we hypothesized that the proportion of children meeting PA guidelines would vary significantly between cutpoints.

3.3 Methods

3.3.1 Study population and protocol

This study analysed baseline data of children between 1.5 and 6 years-old who were enrolled in Guelph Family Health Study (GFHS). The GFHS is a longitudinal, cohort study that seeks to test the effectiveness of a family-based, health promotion intervention and to identify early life risk factors for obesity and chronic disease. To be eligible for the study, families must have at least one child between the ages of 1.5 and 6 years old and live within Guelph or surrounding area. Parents reported that children were typically developing with no known health concerns at the time of testing. Parents provided informed written consent for their children's participation while children provided verbal assent and the study was approved by the University Research Ethics Board (REB# 17-07-003).

There were a total of 246 families enrolled in the GFHS including 322 children; baseline data was collected between August 2017 and March 2020. A total of 40 children refused to wear the accelerometer and 3 children were excluded due to device initialization errors. Additionally, 14 children wore the device, but parent log sheets were not competed; upon visual inspection of the data these participants were removed due to suspected undocumented device removal times. Three children did not meet wear time criterion resulting in a total of 262 children who were included analyses.

3.3.2 Anthropometrics

Children's height and weight were measured by trained study staff. Children were fully clothed (without shoes) for height measurements (ShorrBoard ® Pediatric Measuring Board; Weigh and Measure, LLC, Maryland, USA) and were instructed to stand straight and look forward (or lie down and look up at the ceiling). Two measurements were taken to the nearest 0.1 cm and the average of both measurements was recorded. Weight was measured using a calibrated BOD POD® (NIFS, Indiana, USA) scale and recorded to the nearest 0.001 Kg. BMI z-score for age was calculated using the R software version 4.0.2 (R Core Team, 2017) package "zscorer" (Myatt & Guevarra, 2019).

3.3.3 Accelerometer data

Physical activity was measured by ActiGraph wGT3X-BT accelerometers (ActiGraph™, Pensacola, FL) initialized at a sample rate of 100 Hz, with the idle sleep mode enabled to preserve battery life. Devices were secured over the right iliac crest with an elastic band and children were asked to wear the accelerometer for 7 days, 24 hours per day. Parents were instructed that the device was only to be removed for water-based activities such as swimming or bathing and were asked to fill in a log sheet to track removal times and sleep/wake periods.

3.3.3.1 Removal of non-wear times

All accelerometer data was analyzed using ActiLife Software version 6.13.1 (ActiGraph, 2012). Data were first downloaded in 1 second epochs with the normal filter enabled. Periods of non-wear time were identified and removed using the algorithm defined by Choi et al. (2011). Parameters for this algorithm were set to identify nonwear time as any 1 minute interval with consecutive zero counts for greater than or equal to 60 minutes, with allowance for a 2 minute interval of non-zero counts during 30 minutes upstream and downstream (Choi et al., 2011). This algorithm has been validated in youth and adults aged 10-67 years (Choi et al., 2011); to our knowledge, no current consensus exists in the literature regarding the preferred algorithm for study populations including young children, in fact this information is often not reported in published papers (Cain et al., 2013a; Migueles et al., 2017). Subsequently, data were visually inspected, and cross checked with the parent reported log sheets to identify and remove exact non-wear times and daytime napping periods from the data using the log diary function in the scoring tab of the ActiLife software.

3.3.3.2 Removal of Overnight Sleep periods

For each participant, a second file was downloaded in 60 second epochs with the low frequency extension feature selected for processing of sleep data. This option lowers the amplitude threshold, thereby allowing lower amplitude movements to be included in the acceleration signal (ActiGraph, 2018), and has been suggested to increase sensitivity when detecting sleep periods (Coyle-Asbil et al., 2020; Tudor-Locke et al., 2014). These files were then analysed using the Sadeh et al. (1994) to identify sleep/wake states and the Tudor-Locke et al. (2014) algorithm was used to detect sleep periods. The sleep/wake times identified using the Sadeh and Tudor-Locke algorithms were subsequently, cross checked with the parental reports and the data were visually inspected. These times were then added to the log diary function in the scoring tab of the software to remove overnight sleep periods from the data.

Table 3.1: Summary of cutpoint calibration studies from hip-worn ActiGraph devices and resulting cutpoints used

Authors	Population	Device	Protocol	Criterion	Cutpoints SED	LPA	MVPA
Trost et al 2012	16 – 35 mo N= 22	• GT1M • 30Hz • 15s epochs	• 20 mins videotaped free-play session • CARS scoring SED: <2, LPA:2.0 -2.99, MVPA: >=3 • Weighted average = CARS score * percent of 15s interval spent in that activity code and summing the products	• Modified CARS • 4 levels • Weighted average over 15s	≤195	196 – 1672	1673+
Costa et al (2014) VA	24 – 47 mo N = 18	• GT3X+ • 80 Hz, LFE • 5s epochs	• videotaped semi-structured sessions based on CARS activities • 20 – 30 mins • CARS scoring SED:<2, LPA:>2- <4, MVPA: >=4	• CARS • Averaged over 5s	≤60	61 – 1979	1980+
Costa et al (2014) VM					≤ 1153	1154 – 4342	4343+
Van Cauwenberghe (2011)	4 – 6 yrs N = 18	• GT1M • 30 Hz • 15s epochs	• sitting & standing, listening to story, seated drawing (3 mins each) • walking & jogging on treadmill at 7 speeds (3 mins each?), outside walk at a self-selected pace (10mins) • A free play session (20 mins) was also included	• CARS • Averaged over 15s	≤1491	1492 – 2339	2340+
Pate et al (2006)	3.3 – 5.9 yrs N= 29	• 7164 • 10 Hz • 15s epochs	• Reclined sitting watching TV (10 mins) • Researcher paced walk @2mph, 3mph & jog @4mph (5 mins each) • Cutpoint for MVPA identified via visual inspection of VO2 values for slow walking, brisk walking, + jogging. • **LPA and SED cutpoints added later by author discretion**	• Indirect Calorimetry	≤799	800 - 1679	1680+
Pate&Pfeiffer et al (2009)					≤151	152 – 1679	1680+
Butte et al (2013) VA	3.1 – 5.9 yrs N= 50	• GT3X+ • 30 Hz • 15s/60s epochs	• Watching TV, colouring, video games, playing with child toys, dancing, performing aerobics, running in place, napping. • In between scheduled PA, children were given “free time” to engage in light activities of their choice.	• Room calorimetry & HR • Min-by-min observations	≤239	240 – 2119	2120+
Butte et al (2013) VM					≤819	820 - 3907	3908+
Puyau et al (2002)	6 – 16 yrs N=26	• 7164 • 10 Hz • 60s epochs	• SED: Nintendo, arts & crafts, playtime (20 mins each) • LPA: Aerobic warmup, treadmill walk @ 2.5 mph (10 mins each) • MPA: Tae Bo (10 min), Playtime (basketball, hula hoop, bouncing ball, paddleball, tossing ball, darts, a jumping jacks) (20 min), treadmill walk @3.5mph (6 -7-year-olds) (10 min) • VPA: jogging @ 4.5mph (6 -7-year-olds) (10 mins) • Self-paced jump rope, walk, skip, jog, soccer outdoors (3-5 min)	• Room calorimetry (6 hrs)	≤799	800 - 3199	3200+
Evenson et al (2008)	5.1 – 9.0 yrs N= 33	• 7164 • 10Hz • 15s epochs	• SED: rest, movie, colouring • LPA: slow treadmill walk @ 2 mph • MPA: Paced stair climbing, basketball, brisk treadmill walk @3 mph • VPA: bicycling, jumping jacks, treadmill running. @ 4 mph • All performed for 7 min, data from mins 3 -6 analysed	• Indirect Calorimetry	≤100	101 – 2295	2296+

3.3.3.3 Cutpoint analyses

After non-wear times, daytime naps and overnight sleep times were identified and removed from the data, only children who had a minimum of 360 mins (6 hours) of valid wear time per day for a minimum of 3 days were included in the next stage of our analyses. This inclusion criterion was chosen to maximize the total number of children included in this analysis from our study cohort and has been previously used (Bammann et al., 2011) and shown to produce adequate reliability (Penpraze et al., 2006). After inclusion criterion was met, ten different cutpoints were applied to the 1 second epoch files to determine the average amount of time spent in SED, LPA, MVPA and TPA. These cutpoints were chosen as they have all been calibrated and validated in child populations using ActiGraph devices worn on the hip; a summary of each of these cutpoints and the corresponding calibration study is provided in **Table 3.1.** For calibration studies that published cutpoints validated using both the vertical axis (VA) and vector magnitude (VM)(Butte et al., 2014; Costa et al., 2014) both VA and VM cutpoints were applied to the appropriate axis by selecting the “VM” option in the software when applying VM cutpoints; where appropriate we ensured that the “VM” option was *not* selected for cutpoints validated using VA data. Cutpoint values that were not already presented as options in the ActiLife software were scaled up to 60 second values and manually entered into the software. Note that the Pate cutpoint values offered in ActiLife (https://actigraphcorp.force.com/support/s/article/What-s-the-difference-among-the-Cut-Points-available-in-ActiLife) for LPA and SED do not match values that have been cited in the literature (Pfeiffer et al., 2009). Although both the software and Pfeiffer et al. (2009), cite the same calibration study (Pate et al., 2006), that study does not include cutpoint values for SED and LPA, therefore it is possible that these values were determined using author discretion. To quantify the differences caused by these discrepancies, the Pate cutpoints offered in ActiLife (Pate et al., 2006) and those cited by Pfeiffer et al. (2009) (Pate & Pfeiffer) were included in this analysis. It is important to note that when applying cutpoints within the ActiLife software to non-60 sec epoch files, each epoch is multiplied by the value required to equal 60 seconds, as all cutpoints are based on 60 second epochs within the software (https://actigraphcorp.force.com/support/s/article/How-are-Cut-Points-Calculated).

Therefore, for the current analyses, all count values obtained for each 1 second epoch would have been automatically multiplied by 60 and then classified as either SED, LPA or MVPA based on the specific cutpoint applied.

Data was then exported in .csv format, since not all cutpoints have thresholds for MPA and VPA, only SED, LPA and MVPA were exported. TPA was calculated by adding LPA and MVPA. Data from all valid days (range from 3 to 9) was then aggregated to obtain the mean amount of time spent in SED, LPA, MVPA and TPA for each subject. For Aim 1 of this study, all cutpoints were applied to all participants. Due to the rapid changes in development during the early years, physical activity patterns are likely age dependent, which suggests that accelerometer output could be age dependent (Oliver et al., 2007). Recently, it has been recommended to use different cutpoints for different age ranges during the early years (Migueles et al., 2017). Therefore, to address Aim 2 of the study, subjects were divided into three age groups. Children aged 1.5 to 2 years were categorized as Toddlers (n=96) and the Trost (Trost et al., 2012), Costa VA and Costa VM (Costa et al., 2014) cutpoints were applied to children in this group as these cutpoints were developed on children as young as 1-2 years old. The remaining children aged 3 to 6 years were placed in the Preschoolers group (n = 166). The Van Cauwenberghe (van Cauwenberghe, 2011), Pate (Pate et al., 2006), Butte VA (Butte et al., 2014), Butte VM (Butte et al., 2014) and the Pate & Pfeiffer (Pfeiffer et al., 2009) cutpoints were applied to children in the Preschoolers group as these cutpoints were generally developed on children between the ages of 3 and 6 years. Due to the rapid development and changes in motor skills between the ages of 3 – 6 years (Branta et al., 1984; Dosman et al., 2012), a subsample was created from the preschoolers group of children aged 5 – 6 years old (n = 45). The Puyau (Puyau et al., 2002) and the Evenson (Evenson et al., 2008) cutpoints were applied to children in this subsample, called the School Aged group, as they were developed using populations that included children 5 or 6 years and older. For Aim 3 of this study, children were labelled as having met the PA guidelines if their average time spent in MVPA or TPA satisfied the Canadian recommendations for their age group. Subsequently, children aged 1 to 2-years-old were labelled as having met the guidelines if they achieved an average of at least 180 mins of TPA with at least 1 minute of TPA

(Lee et al., 2017; Tremblay et al., 2017). Children 3 to 4 years old were labelled as having met the guidelines if they recorded an average of at least 180 mins of TPA with a minimum of 60 mins of MVPA (Tremblay et al., 2017). Finally, children aged 5 and 6 years old were labelled as having met the guidelines if they achieved an average of at least 60 mins of MVPA (Tremblay et al., 2016).

3.3.4 Statistical Analysis

Descriptive statistics were first calculated to describe the study participant's characteristics in terms of proportions, means and SDs. The mean minutes per day spent in SED, LPA, MVPA and TPA were then calculated twice, first using all cutpoints for the entire study sample population (Aim 1), and second using age appropriate categorical cutpoints (Aim 2). Four different 1-way repeated measures ANOVAs were conducted with "cutpoint" as the within subject factor and PA intensity (SED, LPA, MVPA and TPA) as the dependent variable (Aim 1). For aim 2, four different 1-way repeated measures ANOVAs were conducted for each intensity within three age groups: Toddlers, Preschoolers and School Aged for a total of 12 different 1-way repeated measures ANOVAs.

Cochran's q tests were conducted to investigate differences in the proportion of children meeting age-appropriate PA guidelines for data following the application of age appropriate cutpoints within each age group (Aim 3). As this statistical test assumes that all participants are not related, any siblings that were within the same age group were identified and the younger (or in the case of twins, the second sibling) was removed. In the Toddler group, 3 siblings were excluded resulting in a new sample size of 93, 23 siblings were identified and removed from the Preschoolers group reducing the sample size to 143 and in the School Aged group, 2 siblings were excluded reducing the sample size to 43. Post hoc testing was conducted with McNemars tests to analyse pairwise comparisons of the number of children meeting guidelines according to each cutpoint within each age group. All statistical testing was completed in SPSS version 26 (IBM Corp, Armonk, New York); test assumptions were verified, and corrections were applied, where necessary. The level of significance was set at the $p < 0.05$ level.

3.4 Results

Descriptive statistics for age, anthropometry, ethnicity, and household income for the final study sampled for Aims 1 and 2 are reported in **Table 3.2.**

Table 3.2: Characteristics of study population for the entire sample population (N =262) and by age group to address Aims 1 and 2.

	Everyone	**Toddlers**	**Preschoolers**		**School – Aged**
	(N =262)	**(1 – 2 yrs) (N = 96)**	**(3 – 4 yrs) [a] (N =121)**	**(3 – 6 yrs) [b] (N =166)**	**(5 – 6 yrs) (N= 45)**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Age (years)	3.6 (1.3)	2.2(0.4)	3.9 (0.6)	4.4 (0.9)	5.6 (0.3)
Height (cm)	99.3 (10.2)	88.3 (5.0)	101.7 (5.7)	104.7 (7.3)	112.7 (4.7)
Weight (kg)	15.9 (3.3)	13.0 (1.7)	16.6 (2.2)	17.6 (2.9)	20.2 (2.8)
BMI zscore for age	0.56 (1.0)	0.86 (1.1)	0.44 (0.84)	0.40 (0.9)	0.32 (1.1)
Valid Wear Time (mins /day)	714.2 (72.1)	681.4 (75.6)	727.6 (57.2)	733.2 (62.9)	748.2 (74.8)
Sex (n)					
Male	126	40	60	86	26
Female	136	56	61	80	19
Ethnicity (n)					
White	192	78	85	114	29
Other	70	18	36	52	16
Household income (n)					
Did not answer	10	2	6	8	2
<$100,000	122	45	53	77	24
$100,00+	130	49	62	81	19

[a] Sample used for determining whether children aged 3 to 4 years olds met the PA guideline of ≥ 180mins of TPA with ≥60 mins of MVPA

[b] Sample used for the portion of the analysis that divided the sample into age categories to apply age-appropriate cut points. Note that this sample contains the same children that were included in the Preschoolers, 3 to 4 years and the School Aged, 5 to 6-year group in this table.

3.4.1 Aim 1 Effect of cutpoint on the entire sample

Figure 3.1 illustrates mean amount of time (mins) spent in SED, LPA, MVPA and TPA for all subjects calculated using all included cutpoints and how the amount of time spent in each intensity varies depending on what set of cutpoints is applied to the data. The Van Cauwenberghe (van Cauwenberghe, 2011) cutpoints resulted in the largest amount of time spent in SED (614.7 mins) and the least amount of time in TPA (98.9 mins) while the Butte VM (Butte et al., 2014) cutpoints resulted in the smallest amount of time spent in SED (437.2 mins) and the largest amount of time in LPA (176.4 mins), MVPA (100.7 mins) and TPA (277 mins). Repeated measures ANOVAs with a Greenhouse-Geisser correction showed a significant effect of cutpoint on the amount of time spent in **SED** ($F(1.74, 455.19) = 6035.84$, $p = <0.001$, $\eta^2 = 0.96$), **LPA** ($F(1.79, 468.12) = 6577.54$, $p = <0.001$, $\eta^2 = 0.96$), **MVPA** ($F(1.88, 489.81) = 2633.43$, $p = <0.001$, $\eta^2 = 0.91$) and **TPA** ($F(1.68, 438.93) = 6151.27$, $p = <0.001$, $\eta^2 = 0.96$) (**Supplementary Table 3.3**). Post hoc comparisons using a Bonferroni correction revealed a significant difference for time spent in all intensities across all cutpoints, with a few exceptions. Pairwise comparisons for time spent in SED revealed that the Trost (Trost et al., 2012) vs Butte VA (Butte et al., 2014) cutpoints and the Pate (Pate et al., 2006) vs Puyau (Puyau et al., 2002) cutpoints produced identical results (515.1 mins and 574.9 mins, respectively) and there was no significant difference between the Costa VA (Costa et al., 2014) and Evenson (Evenson et al., 2008) cutpoints (500.9 mins vs 501.3 mins; $p = 1.00$). For time spent in MVPA, pairwise comparisons showed that the Trost (Trost et al., 2012) , Pate (Pate et al., 2006) and Pate & Pfeiffer (Pfeiffer et al., 2009) cutpoints all produced identical times (90.7 mins); the Van Cauwenberghe (van Cauwenberghe, 2011) vs Evenson (Evenson et al., 2008) cutpoint comparison also revealed no significant differences (67.08 mins vs 67.13 mins; p=1.00). Pairwise comparisons for time spent in TPA revealed that the Trost (Trost et al., 2012) vs Butte VA (Butte et al., 2014) cutpoints and Pate (Pate et al., 2006) vs Puyau (Puyau et al., 2002) cutpoints produced identical times (199.1 mins and 139.3 mins, respectively); there was no significant difference between Costa VA (Costa et al., 2014) and Evenson (Evenson et al., 2008) cutpoints (212.7 mins vs 212.9 mins; $p = 1.00$). Additionally, differences were found in all intensities between the Costa VA and Costa VM (Costa et al., 2014) and between the Butte VA and Butte VM (Butte et al., 2014) cutpoints.

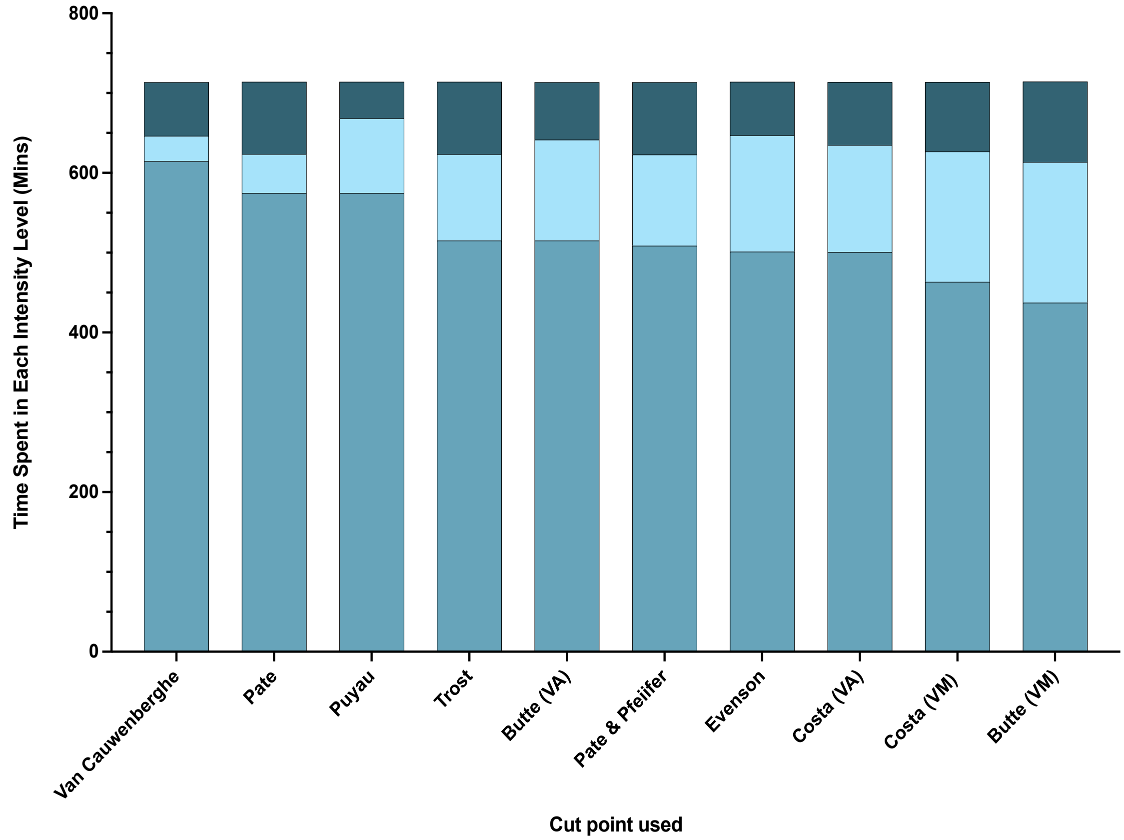


Figure 3.1: Calculated average minutes per day (total of 714.2 minutes of valid wear time) spent in SED, LPA, MVPA and TPA according to the ten different ActiGraph cutpoints examined. Cutpoints were applied to the entire cohort for Aim 1 of our study analysis.

3.4.2 Aim 2: Effect of age appropriate cutpoints on corresponding age categories

Figure 3.2 presents mean minutes spent in each intensity when age appropriate cutpoints were applied to participants within the appropriate age category. Repeated measures ANOVAs with Greenhouse-Geisser corrections determined there was a significant effect of cutpoint on the amount of time spent in SED, LPA, MVPA and TPA within each age category. Post hoc comparisons using Bonferroni corrections showed significantly different times spent in all intensities across all cutpoints within all three age categories, with one exception. In the preschoolers age group, the Pate (Pate et al.,

2006) and Pate & Pfeiffer (Pfeiffer et al., 2009) cutpoints produced the same amount of time spent in MVPA (92.44 mins); please see **Supplementary Table 3.4** for details.

3.4.3 Aim 3: Effect of cutpoints on the portion of children meeting PA guidelines

The proportion of children meeting PA guidelines within each age category based on age-appropriate cutpoints is illustrated in **Figure 3.3**. Results from the Cochran's q tests revealed that the proportion of children meeting PA guidelines was significantly different across all cutpoints. McNemars's tests with Bonferroni corrections for multiple testing were then applied to assess all pairwise comparisons in the Toddler and Preschoolers age groups. These pairwise comparisons indicated significant differences in the proportion of children meeting PA guidelines within the Toddler and Preschoolers age groups for all comparisons. The McNemar's test also revealed a significant difference in the proportion of children meeting PA guidelines between the Puyau (Puyau et al., 2002) and Evenson (Evenson et al., 2008) cutpoints in the School Aged group.

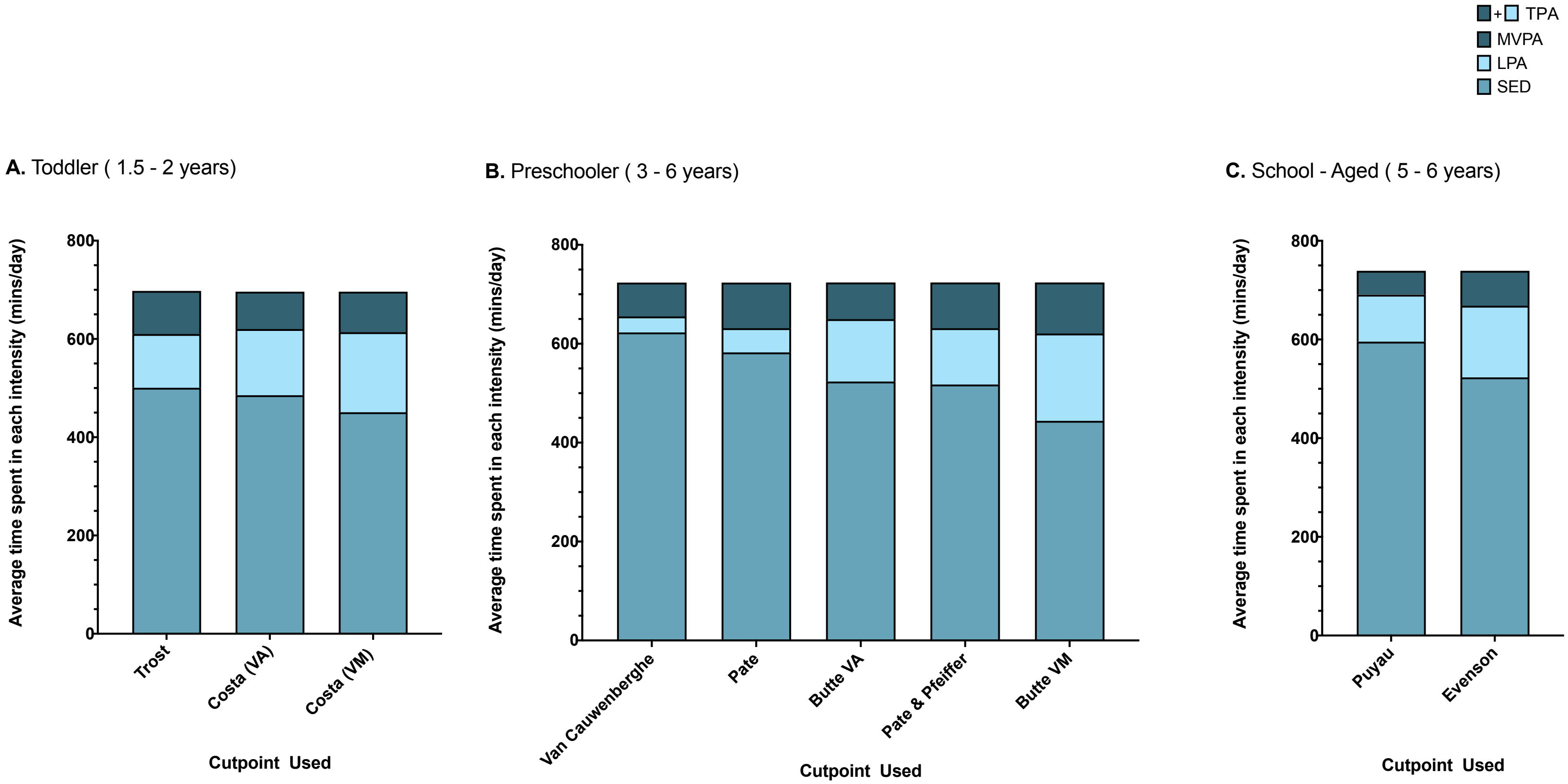


Figure 3.2: Calculated average valid wear time minutes per day spent in SED, LPA, MVPA and TPA according to age-appropriate ActiGraph cutpoints applied to (A) Toddlers (N=96; total 681.4 min), (B) Preschoolers aged 3- 6 years (N=166; total 733.2 min) and a subsample of the preschool aged children (C) School-aged children (N=45; total 748.2 min within the sample for Aim 2 of our study analysis.

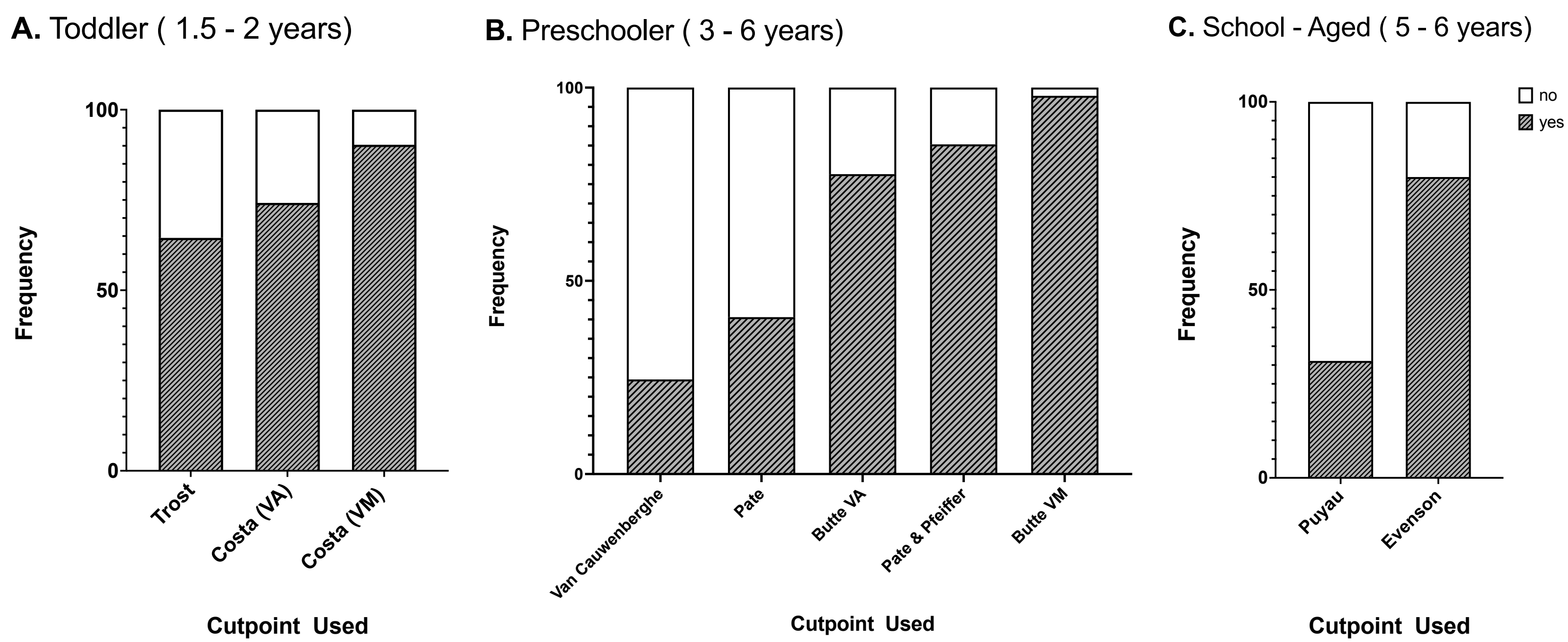


Figure 3.3: Proportion of sample meeting age-appropriate guidelines for PA according to age-appropriate ActiGraph cutpoints applied to (A) Toddlers (n = 93), (B) Preschoolers (n = 143) and (C) School Aged children (n = 43) within the sample for Aim 3 of our study analysis.

3.5 Discussion

Cutpoint non-equivalence has rendered field-based accelerometer cross-study comparisons very difficult and has also presented researchers with numerous decisions they must face when using accelerometers to quantify movement behaviours in young children. The overarching objective of this work was to inform researchers in this area of study how their choice of cutpoint could impact the physiological interpretation of accelerometer-based data. Our results found significant variations in times spent in SED, LPA, MVPA and TPA amongst ten different cutpoints, which are further detailed in the discussion.

3.5.1 Aim 1: Effect of cutpoint on the entire sample

Our results showed that choice of cutpoint significantly effects the amount of time spent in SED, LPA, MVPA and TPA (Figure 1). A few cutpoints produced identical or similar results, however the majority of cutpoints results in significantly different amounts of time spent in each intensity. With differences as large as 177.5 mins for SED, 144.6 mins for LPA, 55 mins for MVPA and 178.1 mins in TPA, these results indicate that comparisons across studies using different cutpoints should be interpreted with caution. Our results indicate that comparability across cutpoints is dependent on the specific intensity of interest as there were no two cutpoints that produced similar results across all four intensities. Similar results have been previously reported in studies investigating the effect of various cutpoints on data from narrower age ranges such as 2 – 3 year olds (Costa et al., 2014), 3 – 5 year olds (Bornstein et al., 2011; Leeger-Aschmann et al., 2019) or 5 – 6 year olds (van Cauwenberghe, 2011). However, these studies made comparisons across just three (Costa et al., 2014) to five (van Cauwenberghe, 2011) different cutpoints, and only two studies reported results for all four intesnities (Costa et al., 2014; Leeger-Aschmann et al., 2019) with one study only comparing estimates of MVPA (Bornstein et al., 2011). Pairwise comparisons suggested that the Trost (Trost et al., 2012) and Butte VA (Butte et al., 2014), Pate (Pate et al., 2006) and Puyau (Puyau et al., 2002) and the Costa VA (Costa et al., 2014) and Evenson (Evenson et al., 2008) cutpoints produced comparable times for SED and TPA. Similar times spent in MVPA were found between the Trost , Pate (Pate et al., 2006) and Pate&Pfeiffer (Pfeiffer et al., 2009) cutpoints as well as between the Van Cauwenberghe (van Cauwenberghe, 2011) and

Evenson (Evenson et al., 2008) cutpoints. Similar results were found by Costa et al. (2014); they reported that the Trost (Trost et al., 2012) and Pate (Pate et al., 2006) cutpoints produced the same amounts of MVPA in their sample. In our data set, all comparisons of time spent in LPA produced significant differences, indicating that no cutpoints are comparable when investigating time spent in LPA. Of particular interest is that times spent in SED and LPA calculated by the Pate (Pate et al., 2006) and the Pate&Pfeiffer (Pfeiffer et al., 2009) cutpoints were significantly different, and therefore authors should ensure they report *exactly* which version of the Pate derived cutpoints were used to limit confusion within the literature. It has been previously suggested that using data acquired from multiple axes, i.e. vector magnitude (VM), may be more appropriate for capturing the multidirectional nature of young children's movement patterns (Leeger-Aschmann et al., 2019). However, our results showed significant differences across cutpoints that were developed using VM derived cutpoints from triaxial ActiGraph devices, indicating that even if studies both implemented VM derived cutpoints, comparisons should not be made across studies. Furthermore, significant differences were also between the Costa VA and Costa VM (Costa et al., 2014) and between the Butte VA and Butte VM (Butte et al., 2014) cutpoints even though these cutpoints were developed using identical protocols during the same calibration studies.

3.5.2 Aim 2: Effect of age appropriate cutpoints on corresponding age categories

Previous research has suggested that cutpoints should be applied to accelerometer data acquired from children the same age as that of the published population used in the original calibration study to improve accuracy (Burchartz et al., 2020; Migueles et al., 2017). To explore this further we applied age specific cutpoints to our sample population for Toddler, Preschool and School Aged children and reported significant differences in times spent in all intensities for each of the different cutpoints applied, despite dividing our sample into age categories matching the age ranges used in the calibration studies. While these results are similar to previous studies (Brazendale et al., 2016; Costa et al., 2014; Leeger-Aschmann et al., 2019; van Cauwenberghe, 2011), our study also included an estimate of all four intensities and only applied cutpoints to the portion of our sample that fell within the age range included in the original calibration studies, while previous studies applied cutpoints developed from populations that fell outside of their sample's age range (Bornstein et al., 2011; Leeger-Aschmann et al., 2019; van Cauwenberghe, 2011). This presents an important point for consideration within longitudinal studies, where children in the sample may fall into different age ranges at different study timepoints; our findings suggest that researchers should consider adjusting cutpoints to match the age of their sample at each timepoint. Simply put, caution should still be taken when making comparisons of times spent in SED, LPA, MVPA and TPA across studies even when investigating sample of the same age ranges.

3.5.3 Aim 3: Effect of cutpoints on the portion of children meeting PA guidelines

Another important implication for choice of cutpoint becomes apparent when investigating the proportion of children that meet current Canadian PA guidelines which are also the same guidelines recommended by the World Health Organization (World Health Organization, 2010b, 2019). Our results showed that when different cutpoints were applied within age-appropriate categories, the proportion of children meeting PA guidelines varied significantly based on which cutpoint was applied. These findings are concurrent with previous studies that showed discrepancies in the number of children meeting PA guidelines with the application of different cutpoints (Leeger-Aschmann et al., 2019; van Cauwenberghe, 2011). Although these studies implemented similar guidelines, they did not apply the age-appropriate guidelines used in this study (World Health Organization, 2010b, 2019). The results from aim 3 of our study are concerning as accelerometer data is often used to determine if a child is meeting current PA guidelines. In addition, these outcome values are frequently used to investigate numerous associations between PA and health in large cohort studies (Gutierrez-Hervas et al., 2020; Leppanen et al., 2021) and is also an important benchmark in the global physical activity matrix which provides report cards on physical activity in numerous countries (Aubert et al., 2018). Of additional concern is the variety of cutpoints used in studies included in the systematic reviews investigating associations between PA and health (Carson et al., 2017; Poitras et al., 2016) which formed the basis for the development of current National PA guidelines (Tremblay et al., 2016; Tremblay et al., 2017). Clearly consensus is needed, even if only at a national level, to ensure that future research is accurately capturing the daily physical activities of young children within specific age categories.

Cutpoint non-equivalence has been well established in the literature, with numerous studies reporting differences for time spent in certain movement intensities (Bornstein et al., 2011; Brazendale et al., 2016; Costa et al., 2014; Janssen et al., 2013; Leeger-Aschmann et al., 2019; van Cauwenberghe, 2011). It has been suggested that instead of relying on cutpoints, other measures such as 'raw' accelerometer data should be examined to improve inter-study comparability (Burchartz et al., 2020). Although this approach may allow for greater comparison across studies, it either eliminates the possibility of dividing data into specific intensities, which is important for investigations between movement and heath behaviours, or is accompanied by a new list of cutpoints validated using raw accelerometer data from which researchers must once again select for analysis of their accelerometer derived metrics for physical activity (Phillips et al., 2013; Roscoe et al., 2017).

Previous studies have presented a possible solution to the cutpoint non-equivalence issue by computing equations to facilitate cutpoint comparisons, i.e., equate outcomes between different cutpoints (Bornstein et al., 2011; Brazendale et al., 2016). However, to date this work has only included five or six different cutpoint values and has focused solely on equating estimates of MVPA. Bornstein et al. (2011) developed conversion equations from a sample of 419 children aged 3 to 6 years to allow comparison of MVPA values from five different cutpoints with percent errors ranging from 6.3 – 38.4 %. Brazendale et al. (2016) built upon this work using a sample from the International Children's Accelerometer Database (ICAD) to develop additional conversion equations for six cutpoints suitable for children aged 3 -18 years and results showed percent errors ranging from 1.3 – 30.1 %. Future research should build on this work and consider equating additional outputs, such as SED, LPA and TPA, across numerous cutpoints as well as device models, sample frequencies and epoch lengths. The development of equivalence ratios of all available cutpoints for all intensities would allow researchers to make more accurate comparisons of findings across studies using different cutpoints within the literature. Additionally, widely used software associated with commonly used commercial devices, e.g., ActiGraph™, could incorporate these equations in their software to make equating estimates across cutpoints more easily accessible.

3.5.4 Strengths and Limitations

Although this study provides important insight into the impact of cutpoints on time spent in four different movement intensities and proportion of children meeting guidelines, there are some limitations that should be acknowledged. Despite using a variety of cutpoints, the lack of a 'gold standard' criterion measure prevented us from examining the *accuracy* of the cutpoints used in this study. However, previous studies have evaluated multiple cutpoints against studies against criterion measures and still reported differences in classification accuracy (Costa et al., 2014; Janssen et al., 2013; Trost et al., 2012). For example, based on classification accuracy obtained from a sample of 4 to 5 year olds, Kahan et al. (2013) recommends use of the Sirard cutpoints (Sirard et al., 2005) for SED and MVPA in comparison to other cutpoints (Evenson et al., 2008; Pate et al., 2006; van Cauwenberghe, 2011), while Janssen et al. (2013) recommends the Evenson cutpoints (Evenson et al., 2008) for the measurement of SED and the Pate cutpoints (Pate et al., 2006) for the measurement of MVPA based on classification accuracies obtained from 4 to 6 year olds. Furthermore, the variety of accepted criterion measures and protocols of calibration studies has likely contributed to the discrepancies in cutpoints available for analysing accelerometer data from children in similar age groups. Researchers wishing to analyse accelerometer data must choose a cutpoint without having a criteria measure; we sought to mimic these circumstances to bring awareness to the impact that choice of cutpoint has on accelerometer data analyses. Although improvements in the use of cutpoints are clearly necessary, the ease of use and interpretability of cutpoints suggests they will be used until a more favourable method is easily available to researchers. Thus, we recommend using the Trost et al. (2012) cutpoints for toddlers (< 3 years old) as these are the only cutpoints that have been calibrated and validated for use in children as young as 16 months old. For preschoolers (3 – 6 years), we recommend the use of the Butte et al. (2014) VM cutpoints due to the larger variety of activities, the use of a triaxial AcitGraph model and the use of indirect calorimetry used in the original calibration study.

Finally, our study used data in 1 sec epoch files instead of matching the epoch files that were used in the original calibration studies of each cutpoint. It should be noted that using a 1 second epoch length has been recommended repeatedly to ensure the sporadic nature of PA in young children is captured (Burchartz et al., 2020; Migueles et al., 2017). Consequently, it is likely that other studies will use 1 sec epoch files when applying cutpoints based on other epoch lengths to their data. Additionally, due to the variation in epoch length, sample rate, accelerometer models and filter settings used across the different cutpoint calibration studies, it is unrealistic to expect studies to follow exact protocols used in the calibration studies. This is especially true given the majority of calibration and validation studies that were completed using older models of ActiGraph devices (e.g., 7164, GT1M); in fact, only two calibration studies have been done using triaxial models (GT3X). As acquiring and integrating acceleration data from three movement planes has potential advantages for measuring the atypical movement patterns (Cliff et al., 2009; Costa et al., 2014), future research should focus on improving comparability between studies using data from newer, triaxial models of ActiGraph.

3.6 Conclusions

To conclude, this study highlights the significant impact of applying different cutpoints on the times spent in SED, LPA, MVPA and TPA and when cutpoints were applied to age-appropriate groups. Results demonstrate that the choice of cutpoint significantly impacts the proportion of children meeting Canadian PA guidelines indicating that researchers should be cautious when making comparisons across studies that used different cutpoints. Ideally, comparisons should only be made across studies that used the same cutpoints for data analyses, or that used cutpoints that produced nonsignificant differences within the current study. Future research should build on previous work, continuing to develop conversion equations to allow comparability across subjects using different cutpoints and ensuring easily accessible, user-friendly methods for implementing such equations.

3.7 Supplementary Material

Supplementary Table 3.3: Calculated minutes spent in SED, LPA, MVPA and TPA according to 10 different ActiGraph cutpoints (Aim 1). All cutpoints were applied to the entire sample (N= 262).

Cutpoint	Mean min/day (standard deviation) [a]			
	SED	LPA	MVPA	TPA
Trost	515.1 (56.8)	108.3 (19.6)	90.7 (24.1)	199.1 (40.4)
Costa VA	500.9 (56.2)	133.9 (23.8)	78.8 (21.7)	212.7 (41.9)
Costa VM	463.4 (51.9)	163.4 (28.2)	86.8 (24.6)	250.2 (47.7)
Van Cauwenberghe	614.7 (62.1)	31.8 (7.2)	67.1 (19.2)	98.9 (25.7)
Pate	574.9 (59.8)	48.5 (10.0)	90.7 (24.1)	139.3 (32.6)
Butte VA	515.1 (56.8)	126.4 (23.3)	72.2 (20.4)	199.1 (40.4)
Pate & Pfeiffer	508.8 (56.6)	114.1 (20.4)	90.7 (24.1)	204.8 (41.1)
Butte VM	437.2 (50.9)	176.4 (29.7)	100.7 (27.2)	277.0 (50.7)
Puyau	574.9 (59.8)	93.6 (20.0)	45.7 (14.5)	139.3 (32.6)
Evenson	501.3 (56.2)	145.8 (26.2)	67.1 (19.2)	212.9 (41.9)
F cutpoint	6035.84	6577.54	2633.43	438.93

SED = sedentary behaviour, LPA = light physical activity, MVPA = moderate-to-vigorous physical activity, TPA = total physical activity, F cutpoint = F-test statistic from 1-way repeated measures ANOVAs with cutpoint as the within subject variable and SED/LPA/MVPA/TPA as dependent variable

[a] Based on an average of 714.2mins of valid wear time

Supplementary Table 3.4: Calculated minutes spent in SED, LPA, MVPA and TPA according to ten different ActiGraph cutpoints. Cutpoints were applied to the appropriate age group based on the population included in the original cutpoint calibration study.

Age Group	Cutpoint	Mean min/day (standard deviation)				Met PA Guidelines? (%) [d,e]		
		SED	LPA	MVPA	TPA		Yes	No
Toddlers [a]	Trost	491.7 (60.4)	107.7 (21.3)	82.0 (24.3)	189.7 (42.5)		64.5	35.5
(1 -2 years)	Costa VA	476.3 (58.8)	132.7 (25.8)	70.7 (21.8)	203.4 (44.0)		74.2	25.8
N = 96	Costa VM	447.7 (55.9)	157.8 (29.5)	74.3 (23.2)	232.1 (47.1)		90.3	9.7
	F cutpoint	474.11*	912.08*	120.62*	442.86*	Cochran's q	35.28*	
Preschoolers [b]	Van Cauwenberghe	628.9 (54.5)	33.0 (6.7)	71.3 (18.1)	104.3 (24.0)		24.5	75.5
(3 - 6 years)								
N = 166	Pate	588.0 (52.5)	49.4 (9.4)	95.8 (22.5)	145.2 (30.5)		40.6	59.4
	Butte VA	528.7 (50.5)	127.4 (22.0)	77.1(19.1)	204.5 (38.3)		77.6	22.4
	Pate & Pfeiffer	522.9 (49.8)	114.5 (19.3)	95.8 (22.5)	210.3 (39.0)		85.3	14.7
	Butte VM	445.8 (46.6)	178.9 (28.4)	108.5 (24.9)	287.4 (48.0)		97.9	2.1
	F cutpoint	5305.55*	5768.84*	1548.23*	5305.55*	Cochran's q	285.40*	
School Aged [c]	Puyau	598.0 (60.0)	97.5 (20.2)	52.7 (15.3)	150.2 (33.4)		32.6	67.4
(5 – 6 years)	Evenson	526.4 (54.0)	146.0 (26.8)	75.8 (20.2)	221.8 (43.4)		81.4	18.6
N = 45	F cutpoint	1652.25*	1076.58*	897.93*	1652.25*	McNemar's		p <0.001

SED = sedentary behaviour, LPA = light physical activity, MVPA = moderate-to-vigorous physical activity, TPA = total physical activity
F cutpoint = F-test statistic from 1-way repeated measures ANOVAs with cutpoint (independent) and SED/LPA/MVPA/TPA (dependent)
[a] Based on avg of 681.4 mins of valid wear time, [b] Based on avg of 733.2 mins of valid wear time, [c] Based on avg of 748.2 mins of valid wear time
[d] Guidelines for toddlers: ≥ 180 mins of TPA with ≥ 1 min of MVPA, for preschoolers: ≥ 180 mins of TPA with ≥ 60 mins of MVPA, for school-aged children: ≥60 mins of MVPA
[e] Siblings were removed for this portion of the analysis, yielding the following sample size for this analysis: Toddlers n = 93, Preschoolers n = 143, School Aged n= 43
**Note: In the preschoolers age group, children aged 3 to 4 years were counted as "yes" if they acquired an average of ≥180mins of TPA with ≥ 60mins of MVPA, while children aged 5 to- 6 years were counted as "yes" if they acquired an average of ≥ 60 mins of MVPA*

Chapter 4. Dissertation Progress Summary 1

4.1 Key Findings

A summary of research questions, study objectives and results for Studies 1 and 2 are presented in **Figure 4.1.**

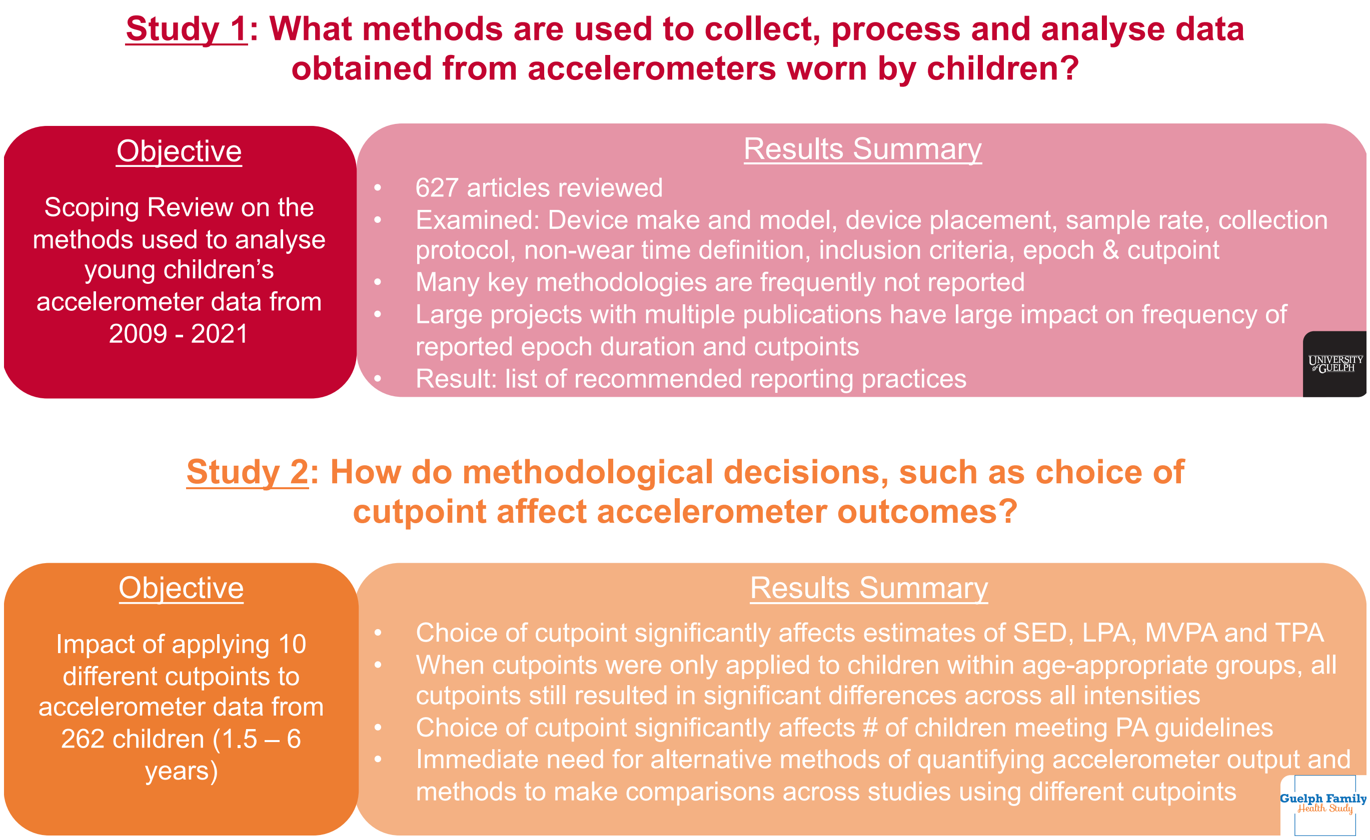


Figure 4.1: Outline of research questions, objectives, and summary of results from Studies 1 and 2.

4.1.1 Study 1

As a result of recent technological advances which have facilitated the use of inexpensive devices to track movement behaviours, there are literally hundreds of published research articles that use accelerometers to investigate physical activity and sedentary behaviours in children. Although accelerometers are not without limitations in their capabilities to provide information on multi-segmental acceleration, movement context and non-weight bearing activities, they provide a suitable and practical alternative to methods with high researcher/participant burden (indirect calorimeter or direct observation) and methods subjected to reporting biases (survey/questionnaires).

Results from Study 1 are summarized in Figure 4.1. Findings showed that the number of research articles using accelerometers in young children has steadily increased over the last eleven years, with over sixty articles published every year since 2017 and over one hundred articles published between January 2020 and March 2021. ActiGraph devices were by far the most reported (75%) and of the 21 different device locations cited, the most common was placement at the hip/waist (n = 459). A large finding of this study was the lack of reporting of key methodological details. Of particular importance is that over 80% of the included articles did not report which sample frequency was used during data collection. Although some accelerometers only have one possible sample frequency, this method should always be reported to allow for comparison with previous and future device models as well as studies examining raw acceleration data. The definition of non-wear time was also frequently not reported (n=203), which limits the information available to researchers conducting studies in pediatric populations.

Another major finding from this scoping review was the representation that large projects with multiple publications have on two specific methodologies within this body of literature: choice of epoch and cutpoint. The most obvious example of the influence/representation of large projects on reported epoch durations was apparent with the number of times that 15 second epochs were reported. This epoch duration was used in 329 articles, however 108 of those publications originated from only 14 studies using the same data set. The impact of large projects was also clear in the use of certain cutpoints, for example Evenson et. al. (2008) cutpoints were reported a total of 110 times, over half of which (n = 68) were reported in articles originating from 12 projects. This frequency sub analysis revealed that large projects, using the same or similar methods increase the number of times a specific epoch duration or cutpoint is reported in the literature. These findings should encourage researchers to choose data processing methods based on what is most suitable for their *own research aims* and not based on what is most frequently reported in the literature.

Subsequently, the plethora of cutpoints used for quantifying accelerometer outputs into different movement intensities emphasizes the major lack of methodological consistency and consensus in the literature. Studies using ActiGraph devices alone cited 41 different cutpoints for preschool aged children. The sheer number of available cutpoints has greatly impacted our ability to compare results across studies. Until a more suitable method of quantifying accelerometer outputs into movement intensities or activities is widely available, accurate reporting of cutpoints applied, software and version used to process data, will aid in the facilitation of broader interpretations of accelerometer data. We created the following list of recommended reporting practices to be detailed in every study using accelerometers in young children with the goal of encouraging researchers to develop better data collection protocols and implement data analysis plans from a better-informed lens:

1) Make and model of device used should be reported
2) Device placement should be reported
3) Sample frequency should be reported
4) Citation of the original calibration study and the actual cutpoint values per chosen epoch should be reported if using a cutpoint
5) The method used to identify and remove non-wear times should be reported.

4.1.2 Study 2

In Study 2, we learned that the choice of cutpoint significantly impacts estimates of the amount of time a sample of young children spent in different movement intensities assessed via accelerometry as summarized in Figure 4.1. These findings highlight the lack of comparability between studies using different cutpoints and accompanying consequences on the interpretation of associations between meeting physical activity guidelines and health outcomes in young children. As cutpoints were calibrated using populations of different age ranges, they should only be applied to sample populations within the specific age range for which they were developed. However, we found that even when age specific cutpoints were applied, significantly different amounts of time spent in all intensities were still found and more critically also resulted in significantly different numbers of children meeting PA guidelines. These results further highlight that PA estimates from studies using different cutpoints are incomparable, regardless of the sample population age. The extreme variability in protocols used in the calibration studies (i.e. activities, criterion measures, settings) coupled with the sporadic nature of movement patterns in young children has results in a wide variation in available cutpoints. Until necessary improvements can be made in the methods used to quantify accelerometer outputs, we recommend using the Trost et al. (2012) cutpoints for toddlers (< 3 years old) and the Butte et al. (2014) VM cutpoints for preschoolers (3 – 6 years). The Trost et al. (2012) cutpoints are recommended as these are the only cutpoints that have been calibrated and validated for use in children as young as 16 months old and the Butte et al. (2014) VM cutpoints are preferred due to the wide variety of activities, the triaxial AcitGraph model and indirect calorimetry used in the original calibration study.

Findings from this study demonstrate how choice of cutpoint can significantly impact the movement behaviour estimates of young children which has further implications on PA recommendations and potentially impacts the interpretation of relationships between PA and health outcomes. There is a recent drive towards the use of raw accelerometer data instead of relying on count data to avoid the use of cutpoints. Before this approach is successful, a consensus from experts in the field is needed to distinguish which raw accelerometer outputs (i.e., acceleration values or activities) are classified into each intensity of movement (sedentary behaviour, LPA, MVPA). Due to the wide variety of cutpoints that have already been published in numerous studies examining associations between movement intensities and health outcomes, methods such as equivalency ratios and adjustment coefficients are needed to allow researchers to make comparisons across studies using different cutpoints.

4.1.3 Next Steps

Now that the methodologies currently used to collect and analyse accelerometer data in young children have been extensively reviewed (Study 1) and the impact of certain processing choices (i.e. cutpoints) has been examined (Study 2), a greater understanding of how the resulting estimates of PA and meeting PA guidelines are cross-sectionally associated with individual motor abilities (Study 3) and longitudinally associated with physical fitness (Study 4) is needed. These research objectives are outlined below in **Figure 4.2.**

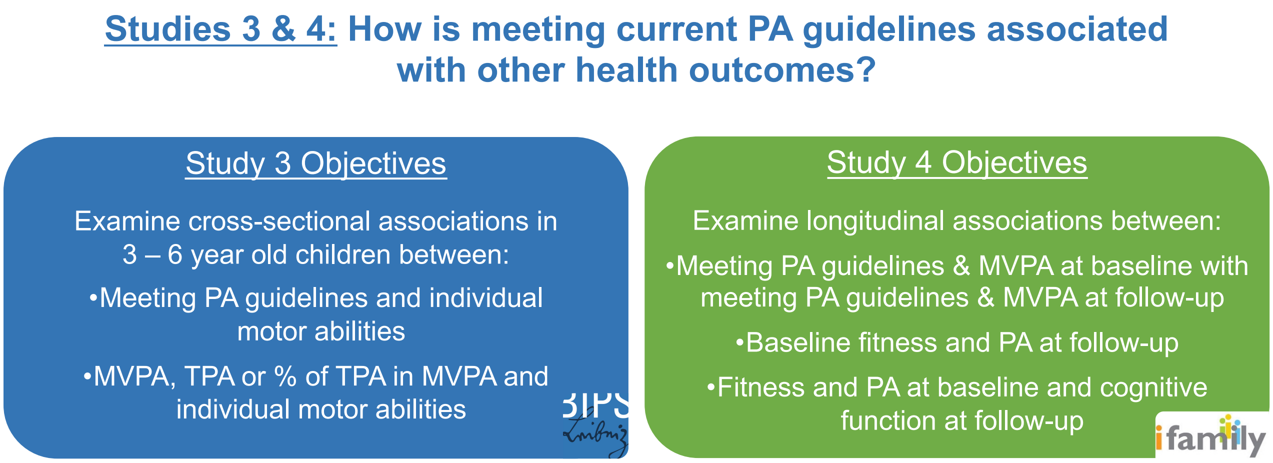


Figure 4.2: Outline of research questions and objectives for Studies 3 and 4.

Chapter 5. Association of individual motor abilities and accelerometer-derived physical activity measures in preschool-aged children

5.1 Abstract

This study explored the relationship between motor abilities and accelerometer-derived measures of physical activity (PA) within preschool-aged children. 193 children (101 girls, 4.2 ± 0.7 years) completed five tests to assess motor abilities; shuttle run (SR), standing long jump, lateral jumping, one leg stand and sit and reach. Four PA variables derived from 7-day wrist-worn GENEActiv accelerometers were analysed including Moderate-to-Vigorous PA (MVPA, mins), Total PA (mins), percentage of total PA time in MVPA and whether children met WHO guidelines for PA. Linear regressions were conducted to explore associations between each PA variable (predictor) and motor ability (outcome). Models were adjusted for age, sex, height, parental education, time spent at sports clubs and wear time. Models with percentage of total PA time in MVPA were adjusted for percentage of total PA time. Regression analyses indicated that no PA variables were associated with any of the motor abilities, but demographic factors such as age (e.g., SR: ß=-0.45, 95%CI: -1.64, -0.66), parental education (e.g., SR: ß=0.25, 95%CI: 0.11, 1.87) or sports club time (e.g., SR: ß=-0.08, 95%CI: -0.98, 0.26) showed substantial associations with motor abilities. Model strength varied depending on the PA variable and motor ability entered. Results demonstrate that total PA and meeting current PA guidelines may be of importance for motor ability development and should be investigated further. Other covariates showed stronger associations with motor abilities such as time spent at sports clubs and should be investigated in longitudinal settings to assess the associations with individual motor abilities.

Keywords: MVPA, Movement, Accelerometry, sports club membership, WHO guidelines, motor skills.

5.2 Introduction

Early childhood (3-5 years of age) presents a critical time for development during which children learn to move through space and acquire fundamental movement skills (FMS) such as running and jumping (Stodden et al., 2008). The development of motor competency is a complex process driven by internal structural and functional changes but is also heavily influenced by environmental factors such as physical activity (PA) (Clark, 1995; Stodden et al., 2008). The complex relationship between PA and motor competency is outlined in a developmental model proposed by Stodden et al. (2008) which suggests that during early childhood, acquisition of FMS is driven by PA. Subsequently, FMS provide the foundation for more complex movements needed for recreational play and sports participation (Gallahue & Ozmun, 2000; Stodden et al., 2008). Accordingly, the model also suggests that during middle to late childhood, motor competency begins to drive PA and therefore, PA during the early years may drive PA during later childhood and adolescence (Stodden et al., 2008).

The relationship between motor competency and PA is critical as we now know that establishing healthy PA habits during early childhood is an important step towards conquering the ongoing childhood obesity epidemic (World Health Organization, 2020). In preschool-aged children, PA, in particular total PA (TPA) and moderate-to vigorous PA (MVPA) has been favourably associated with cardiometabolic health, bone and skeletal health, psychosocial health and both motor and cognitive development (Carson et al., 2017). Despite increased knowledge about the importance of PA, children and youth are spending little time engaging in MVPA (Pate et al., 2015) and continue to score poorly on worldwide PA report cards (Aubert et al., 2018). As this raises concerns for childhood health, PA guidelines targeted towards the early years have become an important area of interest. The World Health Organization (WHO) recently released new guidelines for children under the age of 5, which recommend that children 3-4 years should accumulate a minimum of 180 minutes of any type of PA per day and at least 60 of those minutes should be spent in MVPA (World Health Organization, 2019). For children aged 5-17, the WHO recommends at least 60 minutes of MVPA per day (World Health Organization, 2010b).

The relationship between motor competency and PA has been extensively reviewed (Barnett et al., 2016a; Figueroa & An, 2017; Holfelder & Schott, 2014; Jones et al., 2020; Robinson et al., 2015), and although a relationship is apparent, this association heavily depends on the skills measured and how PA is quantified, as well as the type of analyses conducted, and covariates used. Multiple reviews show a positive relationship between motor competency and PA (Figueroa & An, 2017; Holfelder & Schott, 2014) and a recent meta-analysis of 12 studies indicates a weak but positive correlation between FMS and MVPA and between FMS and TPA (Jones et al., 2020). However, another review conducted by Barnett et al. (2016a) concluded that only certain components of motor competency were related to PA. It is difficult to gain a complete understanding of this relationship due to major inconsistencies in test batteries used to assess motor competency. For example, of 19 studies included in a recent review, ten different assessment tools were used to evaluate motor competency (Jones et al., 2020). Additionally, test items used to evaluate motor competency have also been used to assess other constructs such as fitness (Utesch et al., 2019a; Wrotniak et al., 2006), an issue that is further complicated by the abundance of varying terminologies including; “motor ability”, “motor skills”, “motor coordination”, “motor/movement performance”, and “movement competence” (Robinson et al., 2015). To clarify, the term motor competency is used to describe the proficiency of any goal-oriented form of human movement involving gross body coordination and control (Coppens et al., 2019; Robinson et al., 2015; Utesch et al., 2019b). Thus, during early childhood, fundamental movement skill (FMS) proficiency is often used to evaluate motor competency (Stodden et al., 2008). In contrast, motor abilities can be defined as the general traits or abilities underlying the performance of FMS (Burton & Miller, 1998); examples of motor abilities include speed, endurance, strength, coordination, balance and flexibility and any combination of these abilities, for example speed strength and strength endurance (Burton & Miller, 1998; Klein et al., 2012). In contrast, physical fitness can be defined as “the ability to carry out daily tasks and perform physical activities in a highly functional state” (NCBI, n.d.) as such certain motor abilities such as flexibility may be considered an indicator of good physical fitness. Clinicians, researchers and/or educators may assess these traits through validated movement skills tests such as the Sit and Reach test (Koslow, 1987).

Some evidence suggests an association between PA and individual motor abilities in children. Wrotniak et al. (2006) showed that a higher percentage of time spent in MVPA was correlated with faster speed and agility, as well as greater distance jumped (strength/coordination) in 65 children aged 8 to 10-years-old. In 5- to 6-year-olds, a positive association was found between pedometer derived aerobic steps/day and speed, agility, and balance (Kambas et al., 2012). Unfortunately, most studies calculate one composite score to reflect motor competency, or alternatively calculate subdomain scores for locomotor and object-control abilities (e.g. throwing and catching) (Figueroa & An, 2017; Olesen, 2014; Webster et al., 2019; Williams et al., 2008) rather than specific traits of individual motor abilities. Additionally, many studies use different PA variables (i.e. TPA, LPA, MVPA, VPA) or group all measures of PA together. Although understanding the broad relationship between PA and general abilities is important, research is needed to examine whether PA can impact some specific motor abilities more than others during crucial developmental periods, such as the preschool years. At the present time, little is known about possible associations between PA and individual motor abilities, during the preschool years and how different measures of PA can affect this relationship. The acquisition of proficiency in a variety of motor abilities in the preschool years provides a solid foundation for the development of more complex movement patterns needed later in life, not only for activities of daily living but also for recreational play and participation in sports (Gallahue & Ozmun, 2000; Stodden et al., 2008).

Therefore, the purpose of this study was to evaluate the relationship between individual motor abilities and various objectively assessed PA outcomes within a preschool-aged population. Motor ability tests were conducted to assess speed, strength, endurance, coordination, and flexibility. PA measurements included; MVPA (mins), TPA (mins), the percentage of total physical activity spent in moderate-to-vigorous physical activity (%MVPA of TPA) and whether or not children are meeting current WHO guidelines for PA. Based on previous research (Holfelder & Schott, 2014; Kambas et al., 2012; Wrotniak et al., 2006), it was hypothesized that time in MVPA, TPA, %MVPA of TPA or meeting current PA guidelines recommended by the WHO would be positively associated with all five motor ability tests. Insight into associations between healthy PA habits and individual motor abilities in preschool-aged children will provide critical information for parents and early childhood educators responsible for ensuring children are prepared for the level of social and recreational interactions required for a successful entry to the school years.

5.3 Methods

5.3.1 Protocol

Data for the current study was collected as part of baseline collection from the “JolinchenKids- Fit and healthy in daycare” study. Children between the ages of three and six years were recruited from 61 daycare facilities across Germany. PA data was objectively measured using accelerometers in a subset of these daycare facilities (23 of 61 centres: due to limited availability of accelerometers) in addition to assessment of motor ability. Ethical approval was obtained by the Medical Association in Bremen (HR/RE-522, April 28, 2016), and the study was registered at the German Clinical Trials Register (DRKS00011065). Full study protocol and additional details have been reported by Steenbock et al. (2017).

5.3.2 Data Collection

Two experienced study nurses completed each child’s height and bodyweight measurements while children were barefoot. Height was measured using portable stadiometers (Seca type 213 stadiometer, Invicta Plastics Ltd, Leicester, UK), measurements were recorded to the nearest 0.1 cm. Body weight was measured to the nearest 0.1 kg using the TANITA BC 420 SMA digital scale (TANITA Europe GmbH, Sindelfingen, Germany). Survey data was also collected regarding whether or not the children were members of a sports club and how much time was spent at these sports club weekly. This data was included in our analyses as organized or structured PA has been suggested as an important contributor to motor competency (Burgi et al., 2011; Jaakkola et al., 2009; Vandorpe et al., 2012). In Germany, having a sports club membership in this young age group generally means that children focus on learning to perform fundamental movements skills (i.e. running, jumping, climbing, swinging, balancing and basics in ball games etc.) rather than sports specific training. Courses in sports clubs usually comprise about 30 to 45 minutes of supervised activities. Because sports club membership is not mandatory in Germany, some children do not attend any sports club while others attend more than one sports club per week. As such, children in this analysis were divided into three categories according to parent reports of average time spent at a sports club per week. These categories were: no time a sports club, 30 min – <90 mins per week or ≥90 mins or above per week. Additional survey data was collected on parental education.

5.3.3 Assessment of Motor Abilities

Motor abilities were assessed using five test items including: shuttle run (SR), standing long jump (SLJ), lateral jumping (LJ), one leg stand (OLS) and sit and reach (SAR); details below. The SR test was used to assess movement speed, measured as time (seconds) taken to run from one marked box to another, placed 4 meters apart, two separate times for a total of 16 meters (4 X 4 meters). Each child performed this test once, a faster time indicates better performance on this test. The SLJ test was used to assess speed strength, measured as the maximal distance jumped (cm) with two feet; distance was measured from the starting line to the back of the heel. Children were given one practice trial then two test trials of which the furthest jump was recorded. The LJ test was used to evaluate strength endurance and coordination and was quantified as the number of successfully completed 2-foot jumps over a beam. Two 15-second trials were completed by each child and the sum of the number of jumps for each trial was recorded. The OLS test was used to quantify static balance, measured as the number of times the free leg touched down within 1 minute while standing on a wooden bar (5 cm high). Each child performed this test once, a greater number of touchdowns on this test would indicate poorer performance. Finally, the SAR test was used to assess hip and hamstring flexibility by recording the furthest distance (cm) reached with both hands while seated and legs extended. Each child performed this test once, a negative distance would indicate that the child did not reach past the level of their feet. All tests were administered according to instructions provided in an assessment manual (Klein et al., 2012) by one of two trained study nurses. The two study nurses were trained in a one-day workshop by two of the co-authors of this study. Approximately five children at a time were asked to enter the movement room to perform the test. These children were then tested individually while the others waited in the same room. Results were recorded separately for each test. Children who successfully completed at least one of the five tests were included in this analysis.

5.3.4 Physical Activity Measurements

GENEActiv accelerometers (ActivInsight Ltd. Kimbolton UK) were used to obtain an objective measurement of daily levels of PA. This device contains a triaxial accelerometer with a dynamic range of ±8 g, a 12-bit resolution and has previously been calibrated and used to assess PA in preschool-aged populations (Roscoe et al., 2017; Steenbock et al., 2019). Devices were initialized according to manufacturer's instructions and data was collected at 100 Hz. Written instructions detailing the protocol were given to parents and a logbook was provided for recording periods when the device was not worn (e.g bathing, swimming). Children wore an accelerometer on their left wrist (which is the non-dominant wrist for the vast majority of children); however, previous studies only revealed marginal differences for wearing the accelerometer on the non-dominant vs. the dominant wrist in this age group (Steenbock et al., 2019). The accelerometer was secured with Tyvek wristbands (DuPont de Nemours, Inc., Wilmington, Delaware, United States), for a period of 7 days, 24 hours per day; upon return of the device, data was downloaded using the GENEActiv software (version 2.2; ActivInsight Ltd., Kimbolton United Kingdom). The R software, (version 3.4.3; R Core Team, Vienna, Austria), package "GENEAread" (Fang et al., 2019) was used to process raw data files. First, data collected between 7 pm and 7 am was removed to exclude sleep time from analysis. Following this, periods of non-wear time were identified using range and standard deviation of the raw acceleration value over 60-minute moving windows with 15-minute increments as done previously (Sabia et al., 2014; van Hees et al., 2013). A window was classified as non-wear time if the range of the acceleration value was less than 50mg or if the standard deviation was less than 13.0 mg for at least 2 out of the 3 axes (Sabia et al., 2014). Children with a minimum wear time of 8 hours per day on at least 3 days were included in the analysis as done previously (Barnett et al., 2017). Energy expenditure (EE) in kilojoules was predicted from raw acceleration data using a random forest model trained on data from preschoolers wearing spirometry devices (Steenbock et al., 2019). The resulting estimated EE values were used to determine time spent in TPA (≥7-10 kJ/min) and MVPA (>10 kJ/min). As there are no standardized cutpoints for this age group, these cutpoints were chosen based on previous studies within preschool-aged populations (Brandes et al., 2018; Byun et al., 2016; Roscoe et al., 2017). As current PA recommendations for children highlight the importance of MVPA and TPA, these variables were chosen for part of the analysis. The mean amount of time spent in MVPA and TPA was calculated for each participant. Subsequently, this data was then used to determine whether children met the current WHO guidelines for their age group. For children aged 3-4 years, meeting the WHO guidelines required that they acquired a minimum of 180 minutes of any type of PA, of which at least 60 minutes was spent in MVPA. Children aged 5 years were required to have a minimum of 60 mins of MVPA in order to meet WHO guidelines. Lastly, the percentage of total physical activity time that was spent in MVPA (%MVPA of TPA) was calculated as mean MVPA divided by mean TPA multiplied by 100. This variable was chosen to assess whether spending a greater percentage of their active time in higher intensity PA (MVPA) had a different association with motor ability performance than mean minutes of TPA or MVPA. Therefore, our analysis included four different PA variables; mean MVPA (mins), mean TPA (mins), mean percentage of active time spent in MVPA (%MVPA of TPA), and whether children met the current WHO guidelines for their appropriate age group.

5.3.5 Study Sample

These analyses include a subsample of the 831 children included in the "JolinchenKids- Fit and healthy in daycare" study for whom accelerometry data was collected (N=217). Of these, 24 children were excluded because they were under 3 years of age (n=4), did not complete any motor ability tests (n=2) or did not meet wear time criterion for the accelerometer data (n=18). Thus, the final sample size for our analyses included 193 children aged 3-6 years old.

5.3.6 Statistical Analyses

Descriptive statistics were calculated to describe the study participant characteristics, motor ability tests and PA variables (proportions; means and standard deviations). We conducted linear regression models to investigate the association between each of the four PA variables (MVPA, TPA, %MVPA of TPA and WHO guidelines) with performance on each motor ability test (SR, SLJ, LJ, OLS, SAR) considered as dependent variables for a total of 20 linear regression analyses. Prior to this step, we conducted linear regressions investigating the association only of age, sex, height, parental education, and time spent at a sports club with each motor ability to illustrate the strength of the association between these covariates and individual motor abilities that are used for adjustment regarding PA variables. MVPA, TPA and WHO guideline models were adjusted for mean mins of wear time and the %MVPA of TPA model was adjusted for %TPA to account for variation in wear time. Goodness-of-fit was evaluated in terms of adjusted R^2 to compare models before and after inclusion of PA variables. Level of significance was set to $\alpha = 0.05$ to obtain 95% confidence limits (95%CL) as a precision measure of beta estimates. All statistical analyses were conducted in SPSS (version 26.0; IBM Corp. Armonk, NY, USA).

5.4 Results

Descriptive characteristics for age, anthropometry, motor ability tests and physical activity of the final study sample are reported in **Table 5.1**. In general, boys and girls had similar performance on the motor ability tests, however boys jumped further on the SLJ test (76.0 cm) compared to girls (69.6 cm) and girls reached further on the SAR test (3.8 cm) compared to boys (2.5 cm). Overall, boys had higher amounts of all PA measurements than girls, meaning boys had greater amounts of TPA, MVPA, %MVPA of TPA and met WHO guidelines more often than girls. However, more girls reported having a sports club membership than boys **(Table 5.2**).

Results from the regression analyses on the associations between each PA variable and each motor ability test are presented in **Table 5.3**. All models for SAR did not show a substantial goodness-of-fit (adj. R^2 ranging from 0.02 to 0.04) and therefore will not be presented and discussed further. TPA, MVPA, %MVPA of TPA and Meeting WHO guidelines were not significantly associated with performance on any of the motor ability tests. Due to the exploratory nature of this study, linear regression models which included only covariates and no measure of PA were examined. They showed a significant association of age with performance on motor ability tests. Time spent at a sports club was a significant contributor for the OLS model, specifically spending 30 -90 mins per week at a sports club was associated with less touchdowns during the OLS test. A higher parental education score showed a significant association with decreased performance on the SR tests and nonsignificant but substantial associations with decreased performance on SLJ, and LJ tests. Overall, goodness-of-fit only marginally improved or did not change at all after inclusion of PA variables in all models (**Table 5.3**).

Table 5.1: Descriptive characteristics for the entire sample and by sex

	ALL *(n = 193)*				GIRLS *(n = 101)*			BOYS *(n = 92)*		
	n	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Age	193	4.2	0.7	3.0 to 5.9	4.2	0.7	3.0 to 5.9	4.3	0.7	3.0 to 5.9
Height (cm)	193	106	6.7	89.4 to 124	105	6.7	89.4 to 123	106	6.7	89.8 to 124
Weight (kg)	193	16.8	3.2	10.1 to 34.2	16.5	2.8	10.1 to 29.5	17.1	3.5	11.0 to 34.2
BMI z-score	193	- 0.62	1.3	- 5.0 to 3.4	- 0.56	1.1	- 2.8 to 2.6	-0.69	1.4	- 5.0 to 3.4
Motor Ability Performance										
SR (seconds)	192	11.1	1.9	8.1 to 16.7	11.1	1.8	8.2 to 16.6	11.1	2.0	8.1 to 16.7
SLJ (cm)	192	72.7	22.8	8 to 129	69.6	23.1	10.2 to 129	76.0	22.1	8 to123
LJ (# of jumps)	189	15.2	6.9	0 to 41	16.0	6.9	1 to 33	14.7	6.9	0 to 41
OLS (# of touchdowns)	178	10.3	6.7	0 to 29	10.1	7.1	0 to 29	10.5	6.1	0 to 27
SAR (cm)	192	3.2	4.1	-10 to 12	3.8	4.0	- 9 to 12	2.5	4.2	-10 to 11
Accelerometer Data										
MVPA (min/day)	193	72.4	29.0	22 to 184	63.0	22.2	23 to 147	83.8	32.0	22 to 184
TPA (min/day)	193	249	61.2	129 to 451	242	58.1	154 to 451	255	64.0	129 to 442
Wear Time (min/day)	193	616	37.5	503 to 703	615	39.0	503 to 695	617	36.1	522 to 703
% TPA	193	40.3	9.7	20.8 to 74.2	39.4	9.5	24.6 to 74.2	41.3	10.0	20.8 to 67.5
% MVPA of TPA	193	28.8	7.5	10.8 to 47.0	26.1	6.6	10.8 to 43.1	32.0	7.2	13.1 to 47.0

Note: negative values for SAR indicate that the children did not reach past their toes

Table 5.2: Frequencies for parental education, sports club membership, PA guidelines

	ALL *(n = 193)*		GIRLS *(n = 101)*		BOYS *(n = 92)*	
	n	%	n	%	n	%
Parental Education Score						
Low	16	8	13	13	3	3
Medium	104	54	59	58	45	49
High	65	34	25	25	40	44
Missing	8	4	4	4	4	4
Sports club membership						
Yes	94	49	54	54	40	55
No	97	50	46	45	51	44
Missing	2	1	1	1	1	1
Time at sports club (mins/week)						
No time	97	50	46	47	51	55
>=30 mins - <90 mins	55	29	30	31	25	27
>=90 mins	35	18	21	22	14	15
Missing	6	3	4	4	2	2
WHO guidelines						
yes	111	58	47	47	64	70
no	82	42	54	54	28	30

Note. WHO guideline for 3-4 years = 180 mins of PA/day, including at least 60 mins of MVPA. WHO guidelines for 5+ years = at least 60 mins of MVPA per day. Whether or not children met WHO guidelines was determined using their average PA data

Table 5.3: Linear regression models regressing all measures of PA on each motor ability test

	SR (seconds)				**SLJ** (cm)				**LJ** (# of Jumps)				**OLS** (#of touchdowns)			
	ß	B	95% CI	Adj R^2	ß	B	95% CI	Adj R^2	ß	B	95% CI	Adj R^2	ß	B	95% CI	Adj R^2
Model 1: No PA variable				.38				.42				.45				.24
Age	-0.45	-1.15	-1.64, -0.66		0.54	16.7	11.1, 22.4		0.71	6.51	4.89, 8.14		-0.47	-4.21	-6.10, -2.31	
Sex	0.01	0.47	-0.42, 0.51		-0.14	-6.22	-11.7, -0.79		0.05	0.62	-0.94, 2.18		-0.04	-0.45	-2.31, 1.40	
Height	-0.19	-0.06	-0.11, 0.00		0.12	0.40	-0.22, 1.02		-0.09	-0.09	-0.27, 0.09		-0.04	-0.04	-0.25, 0.17	
Parental Education																
Medium score	0.22	0.84	0.00, 1.67		-0.13	-6.08	-15.8, 3.68		-0.18	-2.37	-5.17, 0.42		0.05	0.63	-2.70, 3.95	
High score	0.25	0.99	0.11, 1.87		-0.15	-6.98	-17.2, 3.28		-0.17	-2.38	-5.31, 0.56		0.02	0.25	-3.23, 3.72	
Sports Club Time																
≥30 - < 90mins	-0.03	-0.12	-0.64, 0.40		-0.01	-0.41	-6.46, 5.64		0.07	1.07	-0.68, 2.81		-0.18	-2.65	-4.73, -0.57	
≥90mins	-0.08	-0.36	-0.98, 0.26		0.04	2.34	-4.89, 9.56		0.11	1.84	-0.23, 3.91		-0.01	-0.15	-2.53, 2.23	
Model 2: MVPA (mins) [a]				.40				.42				.45				.24
	-0.04	0.00	-0.01, 0.06		0.02	0.02	-0.09, 0.13		0.04	0.01	-0.02, 0.04		0.03	0.01	-0.03, 0.04	
Model 3: TPA (mins) [a]				.40				.42				.44				.25
	0.00	0.00	0.00, 0.00		-0.06	-0.02	-0.07, 0.02		0.02	0.002	-0.01, 0.01		0.10	0.01	-0.04, 0.03	
Model 4: %MVPA of TPA [b]				.38				.43				.44				.24
	-0.04	-0.01	-0.05, 0.03		0.13	0.42	-0.04, 0.87		0.04	0.04	-0.09, 0.17		-0.08	-0.08	-0.23, 0.08	
Model 5: Meeting WHO guidelines [a]				.40				.42				.44				.24
	-0.04	-0.14	-0.61, 0.33		0.07	3.11	-2.51, 8.73		0.02	0.26	-1.36, 1.87		-0.03	-0.33	-2.25, 1.58	

ß = Standardized Coefficients Beta, B = Unstandardized coefficients Beta, 95% CI = 95% Confidence Interval
[a] Adjusted for Age, Sex, height, parental education, sports club time and Wear Time (mean mins)
[b] Adjusted for Age, Sex, height, parental education, sports club time and %TPA
Reference category for sex is Male, Reference category for Parental Education is “low” score.
Reference category for sports club time is no time spent at sports clubs

5.5 Discussion

The importance of motor competency (Robinson et al., 2015; Stodden et al., 2008) and physical activity (Carson et al., 2017) during early childhood is well established, and a relationship between motor competency and PA in preschool-aged children is apparent (Barnett et al., 2016a; Figueroa & An, 2017; Holfelder & Schott, 2014; Jones et al., 2020). This study aimed to investigate this relationship further with specific analyses to explore the association between individual motor abilities and four different measures of physical activity derived from wrist-worn accelerometers. As outlined in the introduction we view motor abilities as the general traits or abilities underlying the performance of fundamental movement skill while physical fitness refers to the ability to carry out daily tasks and perform physical activities in a highly functional state. Our results showed no statistically significant or substantial association between PA variables and individual motor abilities. These findings indicate that the covariates used to adjust the regression model i.e. for age, sex, height, parental education and time spent at a sports club, have a greater impact compared to certain PA variables on the motor abilities in our sample of preschool-aged children.

Results from our study were not similar to previous studies that reported a significant relationship between measures of PA and performance on similar motor ability tests of speed and agility (Kambas et al., 2012; Wrotniak et al., 2006), lower leg explosive strength (i.e. SLJ) (Wrotniak et al., 2006), or balance (Kambas et al., 2012). However, these previous studies were conducted using correlational analyses; clearly when interpreting the relationship between PA and motor abilities, the type of analyses conducted (correlation versus regression) should be carefully considered. Regression analysis can provide greater insight as it enables researchers to adjust the association for multiple confounding factors. Differences in PA measurements also limit the comparability across studies as Kambas et al. (2012) used pedometer derived steps to measure PA and Wrotniak et al. (2006) used a different accelerometer with different cut-off points to determine PA. Additionally, our study population was slightly younger than that of these previous studies as Kambas et al. (2012) studied 5 -6-year olds and Wrotniak et al. (2006) investigated 8 – 10-year olds. Loprinzi and Frith (2017) also found no significant association between meeting PA guidelines and motor skills scores in children aged 3 – 5, however they used composite scores in their regression analyses. Iivonen et al. (2013) also found no significant association between MVPA and performance on the SLJ test in 4-year-old children however, they found that other individual test items, including OLS, were significantly associated with MVPA. Other studies have shown mixed results regarding associations between PA and different measures of motor abilities. One study found that higher total skills score and locomotor skills score was significantly associated with increased time spent in vigorous PA but not MVPA or TPA (Webster et al., 2019) while others reported significant associations between similar tests of motor abilities and measures of PA (Fang et al., 2017; Leppanen et al., 2018). However, these studies slightly differ from ours; for example, Leppanen et al. (2018) derived PA levels from doubly labelled water and Fang et al. (2017) and Webster et al. (2019) used composite motor competency scores in their analysis. Even though Leppanen et al. (2018) administered two of the tests used in the present analysis (shuttle run and standing long jump), they aimed to measure physical fitness which highlights how inconsistent terminology can further complicate comparisons across studies. Furthermore, Webster et al. (2019) used measures of motor competency as the independent variable and PA measures as the dependent variable while our analysis used PA measures as independent variables and motor ability as dependent variables. Although our results showed no significant associations, the tendencies and direction of the associations as well as the strength of our models suggest that certain associations may warrant further investigation. Specifically, associations between TPA and meeting WHO guidelines for PA may be of interest for future research. The relationship between PA and individual skills in preschool-aged children has not yet been fully explored in the literature as authors frequently use composite scores in their analyses which hinders the ability to investigate the effect of PA on the development of specific skills during the early years (Holfelder & Schott, 2014). Comparability across studies which implement different test batteries could be improved if future authors report relationships between PA and similar individual test items.

Our results indicated that age was the strongest contributor to models predicting performance on SR, SLJ, LJ and OLS tests; older children had better performance on all of these tests. This is concurrent with the developmental model proposed by Stodden et al. (2008), which proposes that the relationship between PA and motor competency strengthens with age. Previous research has shown positive associations between motor competency during early childhood and PA levels during adolescence (Venetsanou & Kambas, 2017). Therefore, gaining a better understanding of PA levels and motor abilities of preschoolers may be important for understanding PA and motor competency of children and youth (Stodden et al., 2014). Of particular concern was that over half of the children in our study did not meet the current WHO PA recommendations for their age group, which may have consequences for motor competency and PA levels in the future.

An interesting result was discovered during our analyses regarding how much time children spent at a sports club. Spending an average of 30 to 90 minutes per week at a sports club was significantly associated with increased performance on the OLS test and results for SR and LJ tests showed substantial, but non-significant associations in the regression models in line with the age effect, highlighting a complex interplay between these factors. These results are supported in the literature as Klein (2011), Krombholz (2006) and Birnbaum et al. (2016) all found that having a sports club membership was associated with increased performance on similar motor ability tests. As mentioned previously, sports club participation among this young age group in Germany typically represents “gymnastics” or structured exercises geared towards fundamental movements such as crawling, running and jumping rather than sports specific exercises. Consequently, our findings suggest that the structured and guided PA obtained through sports clubs may be beneficial to the development of specific motor abilities during the early years – or expressed in other words: the quality of PA is at least as equally important as the quantity of PA in young children. This is in agreement with recent evidence which suggests that opportunities for guided instruction on specific movements improves motor abilities (Robinson et al., 2015), therefore having a sports club membership, or attending another form of guided PA sessions, may provide important benefits for the development of motor abilities during the early years (Barnett et al., 2016a).

Although our motor ability tests were selected because they require small amounts of time and limited materials, allowing for effective testing of large groups of children (Klein et al., 2012) the product-oriented scoring method only measures the final product of each test (i.e. distance jumped, total speed). This does not allow for qualitative, or “process-oriented” assessment of test performance. The addition of some qualitative measures (i.e. video analysis or subscales of performance on tests) to give more indication of emerging motor abilities may provide a more comprehensive representation of children’s motor ability. As suggested by Robinson et al. (2015), both process and product-oriented tests should be implemented in order to gain a more complete measure of children’s motor competency. Inclusion of a measure of endurance or aerobic fitness level may be beneficial as cardiorespiratory fitness has also been associated with increased motor proficiency in this age group (Robinson et al., 2015).

Further limitations are presented when working with this age group as certain children may have difficulties understanding the tasks; therefore, performance may have been reduced due to a lack of understanding rather than poor motor ability. As this was an initial concern of study investigators, careful instructions and demonstrations of each test were given to all children by the same trained study nurses to promote consistency across all testing sessions. The addition of perceived motor competency measures could provide further information needed to better understand children’s motor ability and participation in PA as studies have shown that children with higher perceived motor competency are more likely to engage in higher levels of PA (Stodden et al., 2014). Due to the complex, multivariate nature of the relationship between motor competency and PA during the early years, future analyses should explore other accelerometer-derived variables such as predicted energy expenditure, bouts of MVPA or TPA, or sedentary time variables may provide additional information about the associations between motor competency and movement behaviours of preschool aged children. Additionally, researchers should investigate other measures of neurological development such as fine motor skills, coordination, dual tasking, as well as cognitive and social emotional development. Lastly, cross-sectional analysis limits the ability to investigate causal links between PA and motor ability. Previous research indicates that changes in motor abilities are driven by PA during childhood (Barnett et al., 2016b; Burgi et al., 2011) and that the relationship between motor competency and PA strengthens over time (Stodden et al., 2008), therefore longitudinal analyses are required to investigate the impact that motor competency and PA during the early years have later in life. Ultimately, the study sample in the present analysis was underpowered to provide statistical inference on the hypothesized associations.

Despite certain limitations, the present study addresses a current gap in the literature as we provided a detailed analysis of the relationship between multiple measures of PA and individual motor ability tests which is in line with recommendations from Jones et al. (2020) and Holfelder and Schott (2014). An additional strength of this study is the use of objectively measured PA, as energy expenditure was predicted from raw accelerometer data using a model that was developed from children of the same age and country (Steenbock et al., 2019).

5.6 Conclusions

In conclusion, this study did not find significant associations between multiple measures of PA and motor abilities, but other factors such as age and time spent at sports clubs seemed to be important factors. Further investigation is warranted to examine the development of motor abilities and whether environmental factors such as PA, parental education, and sports club membership can influence the process of motor ability development. We also recommend that future research should always include the quality of PA, and not only rely on quantity, especially when associations between PA and motor abilities is targeted.

Chapter 6. Study 4 Longitudinal relationship of physical activity, fitness, and cognitive development: insights from the IDEFICS/I.Family study

6.1 Abstract

Background: The purpose of this study was to examine the associations of early childhood physical fitness and physical activity (PA) with PA and cognitive function during later childhood/early adolescence by accounting for gender differences.

Methods: Children from the IDEFICS/I. Family cohort (age 2.4 – 11.7 years) were included. At Baseline, physical fitness tests were conducted including Flamingo balance, Backsaver sit and reach, Handgrip strength, Standing Long Jump, 40-meter sprint and 20-meter Shuttle run (to estimate cardio-respiratory fitness levels). Actigraph accelerometers were used to measure PA over 3 days at Baseline (ActiTrainer or GT1M) and 7 days at Follow-up (GT3X). Evenson cutpoints were used to determine time spent in moderate-to-vigorous PA (MVPA), and children with ≥ 60 minutes of average MVPA were deemed as having met WHO guidelines at Baseline and Follow-up. Cognitive function was measured by performance on the Hungry Donkey test and a modified version of the Berg card sorting test. Linear and logistic regressions were performed to examine the longitudinal associations between meeting WHO guidelines, MVPA, physical fitness tests, with MVPA and cognitive function. Models were conducted on the entire sample, the sex-stratified sample and on the sample stratified by sex and pubertal status at Follow-up.

Results: Results showed that meeting WHO guidelines at Baseline was a strong predictor of MVPA and meeting WHO guidelines at Follow-up for the entire sample, and for males and females when stratified by sex. This was also true for both the male pre/early pubertal and pubertal groups but true for only the female pre/early pubertal group, and not the female pubertal group. Models also indicated that certain fitness tests including Standing Long jump, 40-meter sprint, Shuttle run and Flamingo balance at Baseline were strong predictors of MVPA and for meeting the guidelines at follow-up. No relevant associations were found between fitness tests or meeting guidelines and cognitive function tests.

Conclusions: Meeting WHO guidelines and certain fitness tests at baseline were strong predictors of MVPA and meeting WHO guidelines at follow-up, but this association varied with sex and pubertal status. Consequently, these findings underline the importance for ensuring sufficient physical activity of children at the earliest stages of life.

6.2 Introduction

In childhood, particularly during the school aged years, physical activity (PA) is favorably associated with numerous health indicators such as adiposity, cardiometabolic indicators and cognitive performance (Poitras et al., 2016). Higher intensities of PA such as moderate-to-vigorous PA (MVPA) are more frequently examined and have consistently shown associations with positive health outcomes (Poitras et al., 2016). Importantly, previous research suggests that PA behaviours can track over time (Jaakkola et al., 2019; Jones et al., 2013) however, there is a lack of longitudinal studies with long follow-up periods that could provide insight into the timing of the decline of PA or the effectiveness of targeted interventions at various stages of childhood.

To encourage increased levels of PA during childhood, the World Health Organization has provided global PA recommendations targeted to children between the ages of 5 and 17 years and recommend a minimum of 60 minutes of MVPA per day (World Health Organization, 2010b). Research supports these recommendations; meeting these guidelines has been shown to be positively associated with lower adiposity, cardiometabolic disease risk and increased physical fitness in children (Poitras et al., 2016).

According to Caspersen et al. (1985), physical fitness represents one’s ability to execute physical activities requiring aerobic capacity, endurance, strength or flexibility. Similar to PA, physical fitness has been deemed a positive indicator of health in childhood and adolescence (Ortega et al., 2008). Although the relationships between PA and physical fitness (Poitras et al., 2016), PA and cognitive function (Biddle et al., 2019; Bidzan-Bluma & Lipowska, 2018), and physical fitness and cognitive function (Donnelly et al., 2016) during childhood and adolescence have been reviewed previously, most studies have examined this relationship from a cross-sectional perspective or have solely examined PA as a determinant of fitness. To our knowledge limited longitudinal studies have investigated PA as a predictor of physical fitness (Huotari et al., 2011; Jaakkola et al., 2019; Jaakkola et al., 2016); most studies have focused on adolescents (Huotari et al., 2011; Jaakkola et al., 2019; Jaakkola et al., 2016) have used a subjective measure of PA (Jaakkola et al., 2016) or had a short follow-up period (Jaakkola et al., 2019). With regards to cognitive function, longitudinal studies have shown that Baseline measures of fitness or PA have been cross-sectionally and longitudinally associated with an increase in cognitive function in 5 year olds in a 9 month follow up study (Niederer et al., 2011) and 10 year olds after a one year follow-up period (Chaddock et al., 2012). Clearly, there is a need for further longitudinal investigations of the associations between physical fitness and cognitive function with objectively assessed PA over longer periods of time. Furthermore, as the transition period between childhood and adolescence is marked by developmental changes (e.g. increase in sex hormones, changes in body anthropometry) which may impact PA and physical fitness (Dumith et al., 2011; Stodden et al., 2008), studies should examine changes the relationship between PA, fitness and cognitive function based on pubertal status.

Therefore, this study aimed to investigate the longitudinal associations between physical activity, physical fitness, and cognitive function from childhood through adolescence. Firstly, we examined the association of MVPA and meeting PA guidelines at Baseline with the same PA measures at Follow-up to examine tracking of PA behaviours over time (Aim 1). Secondly, we examined associations between Baseline levels of physical fitness with MVPA and meeting PA guidelines at Follow-up (Aim 2). Lastly, we examined the associations between Baseline measures of PA (meeting PA guidelines) and physical fitness with Follow-up measures of cognitive function (Aim 3). To examine how this association differed between males and females before and after puberty, all associations were conducted for i) the entire sample, ii) the sex-stratified sample, and iii) the sample stratified by sex and pubertal status at Follow-up. For Aim 1, it was hypothesized that children with higher levels of MVPA and children who met PA guidelines at Baseline, would have higher levels of PA at Follow-up. For Aim 2, we hypothesized that children with better fitness test performance at Baseline would have higher amounts of MVPA, would be more likely to meet PA guidelines (WHO) at Follow-up. Finally, for Aim 3 we hypothesized that children with higher levels of PA and physical fitness at Baseline and would have improved cognitive function measures at follow-up.

6.3 Methods

6.3.1 Study design and population

The IDEFICS/I.Family cohort, registered under ISRCTN62310987, is a population-based study which aimed to examine lifestyle-related diseases in children and adolescents from eight European countries including Belgium, Cyprus, Estonia, Germany, Hungary, Italy, Spain, and Sweden (Ahrens et al., 2011). The IDEFICS study (Identification and prevention of dietary- and lifestyle-induced health effects in children and infants) comprised a baseline survey (T0, September 2007 – June 2008, n=16,299 children aged 2.2-9.9 years) and two follow-up surveys (T1, September 2010 – May 2011, n=11,041 children aged 4-11.9 years), including 2,555 newly recruited children (Ahrens et al., 2014); and T2, only conducted to assess dissemination of the intervention messages (by mail), not the full survey protocol. The follow-up surveys revealed only weak effects of the intervention (De Henauw et al., 2015), thus data from T0 and T1 were pooled together to incorporate a larger sample. Participants from T0 and T1 of the IDEFICS study as well as their parents and siblings were invited to participate in an enhanced third follow-up, the I. Family study (T3, in 2013-2014, n=7,105) which aimed to gather additional information pertaining to the entire family (Ahrens et al., 2017). Requirements with respect to ethics approval and written or verbal (for children aged under 12 years) consent was obtained from local ethics committees by participating centres in all eight countries.

The present analysis included longitudinal data from the IDEFICS baseline and follow-up surveys (T0/T1) as well as data from the I.Family survey (T3). Accelerometer data was collected in a subsample at T0/T1 and T3, physical fitness data was only collected at T0/T1 and cognitive function was only assessed at T3. As these measures were only collected in subsamples of the IDEFICS and I. Family populations, a total of n = 4, 329 children were considered for this analysis. From this smaller sample, an additional n = 19 children were excluded as there was less than 3 years between the baseline (T0 or T1) and follow-up (T3) assessments, as such a total of n = 4310 children were included in the present descriptive analysis. Given our research questions about the associations between physical activity, physical fitness, and cognitive function from childhood through adolescence, children must have i) completed at least one of the fitness tests at T0/T1, ii) provided parent survey information at T0/T1 and T3 and iii) have valid accelerometer data at T3 to be included in the final analyses. To be included in the cognitive function analyses, children must have also completed at least one of the cognitive function tests at T3. Children were not required to have accelerometer data at T0/T1 as a "missing category" was created for those who were not included in the accelerometry subsample. A total of n = 1, 280 children provided valid accelerometer data at T0/T1 and n = 1, 894 children provided valid accelerometer data at T3. The number of children who completed fitness tests ranged from 2, 106 to 4, 230.

6.3.2 Covariate Information

In all centres, children were asked to wear light clothing and remove shoes while height and weight measurements were taken by nurses who were trained to follow standardized protocols. Height was measured to the nearest 0.1cm using a clinical Seca 225 stadiometer (Seca, Hambug, Germany). Weight was measured to the nearest 0.1 kg using a BC420 SMA scale (Tanita, Amsterdam, Netherlands). Body mass index (BMI) was classified (thin/normal or overweight/obese) according to cutoffs established by Cole and Lobstein (2012).

Survey data was collected from parents regarding age, sex, income, and socio-economic status (SES). The highest educational level of parents was classified according to the international Standard Classification of Education (ISCED) to assess SES (UNESCO, 2012). ISCED classifications were collapsed into low (ISECD 0-4) and high (ISCED 5+) categories. An additional missing category was created for any participants who did not have data reported on ISCED status. During I. Family assessments, information on pubertal development (i.e., voice change in boys and occurrence of the first menstrual period in girls) was used to classify children into pre/early pubertal or pubertal status. In some countries, Tanner stages were also assessed, and where information on pubertal status was missing, Tanner stages 1&2 were classified as pre-pubertal and Tanner stage 3 was classified as pubertal (World Health Organization, 2010a).

6.3.3 Physical Activity

Physical activity was assessed using Actigraph accelerometers (Actigraph, LLC, Pensacola, FL, USA) worn on the right hip during waking hours only, full details regarding accelerometer data processing from the IDEIFICS study were previously reported by Konstabel et al. (2014). During the IDEFICS (T0/T1) protocol, children were asked to wear either the ActiTrainer or GT1M device for at least 3 days, including 1 weekend day. For the I. Family (T3) protocol, children were asked to wear either the GT1M or GT3X+ device for a period of 7 days. Previous research has confirmed that activity counts from the vertical axis are comparable between the GT1M and GT3X+ devices (Sasaki et al., 2011), thus activity counts from only the vertical axis were used for this analysis. Devices were set to collect data at a sample rate of 30 Hz and data was downloaded in 15 sec epochs using ActiLife software (version 6, ActiGraph, Pensacola, FL). It should be noted that some centres inadvertently used 60 sec epochs for a considerable portion of their initial data processing, therefore all data were reintegrated into 60 sec epochs. Non-wear time was identified using a 60 minute window, to detect 30 minutes of consecutive zero counts, with a 2 minute tolerance for breaks of non-zero counts as defined by Choi et al. (2011). Participants were included if they had a minimum of 360 minutes of valid wear time on at least one weekday and one weekend day to compromise between accuracy and sample size as discussed in Konstabel et al. (2014). Remaining valid data were then scored using the Evenson cut points scaled up for 60 sec epochs (SED: 0 -100; LPA: 101 – 2295; MPA: 2296 – 4011; and VPA: 4012+) (Evenson et al., 2008). For the present analysis, average minutes per day spent in TPA (LPA+MPA+VPA), MVPA and average valid wear time (mean minutes per day) were calculated. Children were then classified as having met the WHO recommendations for physical activity for ages 5 -17 years if they obtained greater than or equal to 60 mins of MVPA per day based on their average minutes spent in MVPA (World Health Organization, 2010b). As no children under 5 years were included in the PA analyses, only the WHO guidelines for 5 – 17-year-olds were used. A missing category was created for children who did not have valid accelerometer data at T0/T1; only children with accelerometer data at T3 were included in the analyses involving physical activity and fitness.

6.3.4 Physical Fitness Tests

Physical fitness testing was completed during T0 /T1 and the five test items were largely based on the ALPHA health-related fitness test battery which has shown reliability in children and adolescents (Artero et al., 2011; De Miguel-Etayo et al., 2014; Ruiz et al., 2011). Test items included: the Flamingo Balance test (FB), Backsaver Sit and Reach test (SAR), Handgrip Strength test (HGS), Standing Long Jump test (SLJ) and 40-m Sprint test (40mS). Additionally, the 20-meter Shuttle Run test (20mSRT). To be included in the present analysis, children must have completed at least one of these fitness tests. All testing protocols have been described previously (Ahrens et al., 2019; De Miguel-Etayo et al., 2014) and full details are provided in **Supplementary Table 6.7**.

Briefly, during the FB test, children stood on one foot and the number of times their free leg touched the ground within 1 minute was recorded. For the SAR test, children reached as far as possible with one leg out straight, the furthest distanced reached (cm) was recorded. During the HGS test, children squeezed a dynameter (TKK 5101; Takei, Tokyo, Japan) as hard as possible and results were recorded in kilogram force (kgf). For the SLJ test, children were instructed to jump as far as possible and land with feet together, the distance was from the starting point to the most posterior heel was recorded (cm). For the 40mS test, children ran a 40-meter distance as fast as possible, speed was recorded in kilometers per hour (km/h). Finally, the 20mSRT test was administered to assess cardio-respiratory fitness, children were instructed to run 20-meters, back-and-forth while matching their pace to beep signals. Children continued until reaching fatigue or failing to complete the distance before the beep on two occasions. Estimate values of VO2 Max calculated using the Leger equation (Leger et al., 1988) were used for analysis. Note that participants from Italy and Hungary were excluded for this test as Italian centres did not administer the test and Hungary used a different protocol that could not be unified with results from other centres.

6.3.5 Cognitive Function Tests

Cognitive function tests were administered during the I.Family assessments (T3). Two tests were included in the present study; the Hungry Donkey test was used to assess adaptive decision-making ability and the Berg Card Sorting test was used as a measure of cognitive inflexibility. These tests were chosen as decision-making ability and set shifting (cognitive inflexibility) are important components of executive function, which entails the cognitive processes that aid in self-control during goal-directed behaviours (Carlson et al., 2014; Miyake et al., 2000). Favorable associations have been found previously between measures of cognitive function and physical activity and physical fitness during childhood (Donnelly et al., 2016). Additionally, the cognitive processes responsible for cognitive control and evaluation of short-and-long term rewards are still being developed during adolescence (Spear, 2000), thus potential determinants of these cognitive processed warrant further investigation. Details of the tests used in the current analysis are briefly described below, full details are available in **Supplementary Table 6.8.**

6.3.5.1 Cognitive inflexibility

A computerized version of the Berg Card Sorting test was used to assess cognitive inflexibility (Berg, 1948). Children were asked to sort four cards with different colours and symbols according to a particular rule that was unknown to the child. Feedback (i.e. “correct” or “incorrect”) was given after each card was sorted to help the child discover the rule of play. The rule was changed without notice every time 10 cards were correctly sorted in a row, leaving the child to discover the ‘new’ rule. Once the rule was changed, the number of cards sorted according to the previous rule was counted. These were referred to as preservative errors and were measured to assess cognitive inflexibility, a higher number of preservative errors indicates more cognitive inflexibility (Berg, 1948; Mueller & Piper, 2014).

6.3.5.2 Adaptive Decision Making

Decision making ability was assessed using a computerized version of the Hungry Donkey test, a child-friendly version of the Iowa Gambling Task (Coumans et al., 2018; Crone & van der Molen, 2004). A detailed description of this task has been published by Crone and van der Molen (2004). Briefly, children had to help a hungry donkey get as many apples as possible by choosing doors presented on a screen. Each choice resulted in either i) larger immediate rewards but more apples being taken away in the long run (disadvantageous doors) or ii) smaller rewards but a larger number of apples in the long run (advantageous doors). Decision making ability was calculated by subtracting the number of disadvantageous choices from the number of advantageous choices. Children were either classified has "yes", they have adaptive decision-making ability meaning they choose more advantageous doors or "no", there was no indication of adaptive decision-making ability, and the child chose more disadvantageous doors (Bechara et al., 2000; Cortes-Patino et al., 2017).

6.3.6 Statistical Analyses

Descriptive statistics in terms of means, standard deviations and proportions were calculated to describe the study participant characteristics (T0/T1 and T3), fitness test performance (T0/T1), cognitive function test performance (T3) and PA variables (T0/T1 and T3).

6.3.6.1 Aim 1. Baseline PA and Follow-up PA

To assess the longitudinal associations of PA behaviours, we first conducted linear regressions to assess the longitudinal association of meeting PA guidelines at T0/T1 with MVPA at follow-up. Subsequently, logistic regressions were conducted to predict whether children who met WHO guidelines at baseline were more likely to meet WHO guidelines at follow-up. These regressions were adjusted for age, sex, country, ISCED, income, BMI category all at T0/T1; and time between T0/T1 and T3 (gap), pubertal status and valid wear time at T3. These models were conducted for the entire sample, stratified by sex and thirdly, stratified by sex and pubertal status at T3.

6.3.6.2 Aim 2. Baseline Physical fitness and Follow-up PA

To assess the associations between baseline levels of physical fitness with PA measures at follow-up, performance on each fitness test at T0/T1 were all individually regressed onto average time spent in MVPA at T3 using linear regressions. Subsequently, logistic regression models were conducted to predict whether children with higher performance on physical fitness tests at T0/T1 predicted higher likelihood of meeting WHO guidelines at T3. These models were adjusted for age, sex, country, ISCED, income, BMI category, meeting WHO guidelines all at T0/T1; and time between T0/T1 and T3 (gap), pubertal status and valid wear time at T3. All regressions were conducted for the entire sample, stratified by sex and thirdly, stratified by sex and pubertal status at T3.

6.3.6.3 Aim3. PA and Physical Fitness at Baseline and Cognitive Function at Follow-Up

To examine the associations of PA and fitness at T0/T1 with cognitive function test performance at T3, linear regressions were conducted to predict the number of preservative errors at T3 (cognitive inflexibility) and logistic regression were conducted to predict the presence of adaptive decision making ability. First, linear regressions were conducted with meeting WHO guidelines and physical fitness variables as predictors of cognitive inflexibility (Berg Card Sorting Task). Then logistic regressions were conducted with the same predictor variable to predict adaptive decision-making ability (Hungry Donkey test). These models were adjusted for age, sex, country, ISCED, income, BMI category, all at T0/T1; and time between T0/T1 and T3 (gap), pubertal status and valid wear time at T3. Models with physical fitness tests were additionally adjusted for whether children met WHO guidelines at T0/T1. All regressions were conducted for the entire sample, stratified by sex and stratified by sex and pubertal status at T3.

Level of significance for all statistical analyses was set to $\alpha = 0.05$ to obtain 95% confidence limits (95%CL) as a precision measure of beta estimates. In addition, standardized Beta coefficients were calculated. All statistical analyses were conducted in IBM SPSS Statistics (Version 26.0) analytics software.

6.4 Results

Descriptive characteristics for age, anthropometry, PA, fitness test and cognitive function test performance for T0/T1 and T3 can be found in **Table 6.1**. In general, more males met the PA guidelines of ≥ 60 mins of MVPA at both T0/T1 and T3 times points. Performance on most fitness tests was similar between sexes, with females reaching slightly further on the Backsaver Sit and Reach (2.3 cm vs 18.9 cm) and males jumping further on the Standing Long jump test (111 cm vs 102 cm). For both males and females, average MVPA was higher at T0/T1 than at T3, (Females: 48 mins (T0/T1) vs 43 mins (T3), Males: 59 mins (T0/T1) vs 51 mins (T3)). For the cognitive function tests, cognitive inflexibility was similar between males and females (mean # of preservative errors = 10.3 vs 10.4) while a higher number of females were recorded as having an adaptive decision-making ability compared to males (409 vs 388 scored as “yes”).

Table 6.1: Mean, SD and Range of descriptive variables from IDEFICS and I. Family, for the whole sample and stratified by sex.

	All (*n=4310*)				Male (*n = 2149*)				Female (*n=2161*)			
	n	Mean	SD	Range	N	Mean	SD	Range	N	Mean	SD	Range
IDEFICS T0/T1 (Baseline)												
Age [years]	4310	7.5	1.0	2.40 – 11.7	2149	7.5	1.0	3.3 – 11.6	2161	7.6	1.0	2.40 – 11.7
BMI z-score	4310	0.51	1.2	-5.3 – 4.6	2149	0.51	1.2	-5.3 – 4.6	2161	0.51	1.1	-4.7 – 4.0
Valid Wear Time [min./day]	1273	762	143	434 – 1335	604	768	149	435 – 1335	669	757	136	441 – 1257
MVPA [min./ day]	1273	53	24	1– 145	604	59	25	3 – 145	669	48	21	1 – 125
WHO PA guidelines met?[1]												
Yes	448				283				165			
No	825				321				504			
FB [touchdowns]	3338	7.8	6.9	5 – 52	1563	9.0	7.5	2 - 52	1775	6.8	6.1	2 – 39
SAR [cm]	4230	20.1	5.5	0 – 41	2101	18.9	5.4	0 – 35	2129	21.3	5.3	0 – 41
HGS [kgf]	4166	11.0	2.9	2.5 – 26.6	2071	11.6	3.0	2.5 – 26.6	2095	10.4	2.7	2.5 – 24.3
SLJ [cm]	4208	106	23	10 – 197	2089	111	24	10 – 197	2119	102	22	24 – 188
40mS [km/h]	2106	9.4	1.2	6.6 – 15.5	1029	9.2	1.2	6.6 – 14.0	1077	9.5	1.1	6.8 - 15.5
20mSRT [VO2 Max]	2387	47.7	2.8	37 – 60	1159	48.2	3.0	38 – 60	1228	47.1	2.5	37 – 56
i.Family T3 (Follow-up)												
Age [years]	4310	12.6	1.3	7.7 – 16.2	2149	12.6	1.3	9.2 – 15.8	2161	12.7	1.3	7.7 – 16.2
Years between T0/T1 and T3	4310	5.1	1.0	3.0 – 8.8	2149	5.1	1.0	3.0 – 8.8	2161	5.1	1.0	3.0 – 7.0
Valid Wear Time [min./day]	1886	780	101	436 – 1350	916	777	106	453 – 1350	970	783	96	436 – 1262
MVPA Time [min./day]	1886	47	20	0 – 135	916	51	212	0 – 135	970	43	18	6 – 125
WHO PA guidelines met?[1]												
Yes	442				279				163			
No	1444				638				807			
Cognitive Inflexibility [2]	2039	10.4	6.5	0 – 39	1008	10.3	6.2	0 – 34	1031	10.4	6.8	0 – 39
Adaptive Decision-Making?[3]												
Yes	797				388				409			
No	1347				686				661			

[1]WHO PA guidelines for 5 – 17-year-olds of 60 minutes of MVPA. Classified using average MVPA values
[2]Assesed as number of preservative errors observed during the Berg Card Sorting Task
[3]Assessed using the Hungry Donkey test, an adapted version of the Iowa Gambling Task

6.4.1 Aim 1. Baseline Physical Activity and Follow-Up PA

Results from the linear regression models using WHO guidelines at baseline to predict MVPA and WHO guidelines at follow-up are presented in **Table 6.2.** Meeting WHO guidelines for PA at T0/T1 was a significant predictor of increased amounts of MVPA at T3. When stratified by sex, meeting WHO guidelines at T0/T1 predicted increased amounts of MVPA at T3 for both males and females. In the stratified samples by sex and pubertal status at T3, meeting the WHO guidelines at T0/T1 was a strong predictor of increased MVPA at T3 in the pre/early pubertal groups and this was more pronounced in the female (adj. R^2 = 0.29) than males' group (adj. R^2 = 0.21). Meeting WHO guidelines at T0/T1 was a strong predictor of increased MVPA at T3 for the male pubertal group but *not* for the female pubertal group.

Results from the logistic regressions indicated that children who met the WHO guidelines at T0/T1 were much more likely to meet WHO guidelines at T3. For males and females, meeting WHO guidelines at T0/T1 indicated a significantly higher likelihood of meeting WHO guidelines at T3. When stratified by sex and pubertal status at T3, results indicated that children who met the WHO guidelines at T0/T1 were more likely to meet guidelines at T3 in the male and female pre/early pubertal groups. However, this was not as true in the pubertal groups, especially in the female group as meeting WHO guidelines at T0/T1 did not increase the chance of meeting WHO guidelines at T3 in the female pubertal group.

Table 6.2: Aim 1. Linear and logistic regressions examining associations between meeting WHO guidelines at baseline with MVPA and meeting WHO guidelines at follow-up

Does meeting WHO guidelines at baseline predict MVPA at follow-up?						
	n	**ß**	**B**	**95% CI**	**Adj R^2**	***P***
Whole Sample [a]	1886	8.3	.13	5.6, 11.1	.24	**<.00**
Stratified by Sex						
Males [b]	916	9.7	.16	5.3, 14.1	.20	**<.00**
Females [b]	970	7.4	.12	3.5, 11.3	.24	**<.00**
Stratified by Sex and Pubertal status						
Pre/Early Pubertal Males [c]	399	10.8	.17	3.4, 18.2	.21	**.00**
Pubertal Males [c]	473	6.9	.12	1.1, 12.8	.16	**.02**
Pre/Early Pubertal Females [c]	419	14.6	.24	9.1, 20.1	.29	**<.00**
Pubertal Females [c]	507	-.26	.00	-6.1, 5.6	.21	.93

Does meeting WHO guidelines at baseline predict meeting WHO guidelines at follow-up?					
	n	**OR**	**95% CI**	**R^2**	***P***
Whole Sample [a]	1886	2.1	1.5, 3.14	.21	**<.00**
Stratified by Sex					
Males [b]	916	2.5	1.5, 4.1	.19	**<.00**
Females [b]	970	1.8	1.0, 3.2	.21	**.03**
Stratified by Sex and Pubertal status					
Pre/Early Pubertal Males [c]	399	3.8	1.6, 8.9	.24	**<.00**
Pubertal Males [c]	473	1.7	.87, 3.5	.17	.12
Pre/Early Pubertal Females [c]	419	5.0	2.2, 11.7	.27	**<.00**
Pubertal Females [c]	507	.61	.23, 1.6	.20	.33

ß = Beta coefficient, B = Standardized Beta coefficient, 95% CI = 95% Confidence Interval, OR = Odds Ratio
"No" is references category for Meeting WHO guidelines
[a] *Models adjusted for Age, Sex, Country, ISCED, Income, BMI category, Gap, Pubertal Status, Valid Wear Time at T3*
[b] *Models adjusted for Age, Country, ISCED, Income, BMI category, Gap, Pubertal Status, Valid Wear Time at T3*
[c] *Models adjusted for Age, Country, ISCED, Income, BMI category, Gap, Valid Wear Time at T3*

6.4.2 Aim 2. Baseline Physical Fitness and Follow-Up PA

Results from the linear regression models using physical fitness test performance at baseline to predict MVPA at follow-up are presented in **Tables 6.3 and 6.4**. As shown in **Table 6.3**, analysis on the whole sample revealed that increased performance on the SLJ, 40mSt, and 20mSRT at T0/T1 predicted increased levels of MVPA at T3. When stratified by sex, the increased SLJ, 40mS and 20mSRT performance predicted increased MVPA at T3 in the male group, while increased number of touchdowns on the FB test (decreased performance) predicted increased MVPA at T3 for the female group. In the stratified samples by sex and T3 pubertal status, results for the pubertal male group showed that increased performance on the 40mS test (reduced time) was a strong predictor of increased MVPA at T3 and increased SLJ performance was trending as a predictor of increased MVPA at T3. In the female pubertal group, increased touchdowns on the FB test (decreased performance) was the only strong predictor of increased MVPA at T3.

As shown in **Table 6.4** results from logistic regressions showed that some physical fitness tests had statistically significant associations with meeting WHO guidelines at T3 ($p < .05$), but OR were ≤ 1. Specifically, results indicated that increased SLJ performance was associated with meeting WHO guidelines at T3. For males, better performance on the SLJ and 20mSRT was associated with meeting WHO guidelines at T3, no associations were found in the female group. In the male pubertal group, better performance on the SLJ had a statistically significant impact on meeting guidelines at T3, but the OR was equal to 1. The same phenomenon was observed in pubertal females, as decreased performance on the FB test (increased touchdowns) was a statistically significant predictor of meeting WHO guidelines in T3, with an OR of 1.1.

Table 6.3: Aim 2. Linear regressions of associations between physical fitness at baseline and average MVPA at follow-up

Predictor	Whole Sample						Males [b]						Females [b]					
	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*
FB [a]	1597	.03	.01	-.12, .18	.24	.69	731	-.17	-.05	-.39, .05	.21	.13	866	.25	.08	.05, .45	.24	**.01**
SAR [a]	1854	.08	.02	-.08, .24	.24	.34	895	.07	.02	-.18, .32	.20	.58	959	.01	.00	-.19, .21	.24	.91
HGS [a]	1825	-.12	-.02	-.49, .26	.24	.54	882	-.01	.00	-.56, .53	.20	.96	943	-.30	-.04	-.81, .21	.24	.25
SLJ [a]	1834	.06	.07	.02, .11	.25	**.01**	886	.10	.11	.03, .17	.21	**.00**	948	.02	.03	-.03, .08	.24	.40
40mS [a]	926	-1.6	-.09	-2.8, -.38	.21	**.01**	438	-2.4	-.13	-4.2, -.63	.17	**.01**	488	-.57	-.03	-2.2, 1.1	.19	.51
20mSRT [a]	1017	.35	.09	.10, .61	.14	**.01**	471	1.0	.14	.38, 1.7	.16	**.00**	546	.10	.01	-.57, .77	.17	.76

Stratified by Sex and Pubertal status

Males

Predictor	Pre/Early Pubertal						Pubertal					
	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*
FB [c]	296	-.17	-.06	-.48, .15	.23	.30	409	-.23	-.07	-.54, .09	.17	.16
SAR [c]	385	-.13	-.03	-.53, .27	.22	.53	468	.20	.05	-.13, .53	.16	.23
HGS [c]	384	-.74	-.10	-1.6, .10	.22	.08	456	.54	.08	-.24, 1.3	.16	.17
SLJ [c]	384	.09	.09	-.02, .19	.21	.12	459	.09	.11	.00, .18	.17	.05
40mS [c]	164	-2.0	-.11	-5.2, 1.2	.15	.22	252	-3.2	-.18	-5.5, -.91	.13	**.01**
20mSRT [c]	197	1.1	.14	-.05, 2.2	.12	.06	246	.76	.10	-.16, 1.7	.13	.11

Females

Predictor	Pre/Early Pubertal						Pubertal					
	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*
FB [c]	360	.04	.01	-.27, .36	.29	.78	471	.40	.13	.13, .68	.20	**.00**
SAR [c]	412	.20	.05	-.13, .52	.29	.23	504	-.06	-.02	-.33, .22	.21	.69
HGS [c]	406	.23	.03	-.64, 1.1	.29	.60	495	-.58	-.09	-1.2, .08	.21	.08
SLJ [c]	408	.09	.10	-.01, .18	.30	.08	500	.00	.00	-.07, .08	.21	.94
40mS [c]	190	-1.2	-.08	-4.1, 1.6	.18	.39	275	.06	.00	-2.3, 2.4	.18	.96
20mSRT [c]	237	.50	.06	-.54, 1.5	.34	.22	279	-.04	-.01	-.96, .88	.93	.16

ß = Beta coefficient, B = Standardized Beta coefficient, 95% CI = 95% Confidence Interval, FB = Flamingo Balance, SAR = Backsaver Sit & Reach, HGS = Handgrip Strength, SLJ = Standing Long Jump, 40mS = 40-meter Sprint, 20mSRT = 20-meter Shuttle Run

[a] *Models adjusted for Age, Sex, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[b] *Models adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[c] *Models adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Valid Wear Time at T3*

Table 6.4: Aim 2. Logistic regressions of associations between physical fitness at baseline and meeting WHO guidelines at follow-up

	Whole Sample					**Males** [b]					**Females** [b]				
	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*
FB [a]	1597	1.0	.98, 1.0	.20	.88	731	.98	.95, 1.0	.19	.14	866	1.0	1.0, 1.1	.201	.07
SAR [a]	1854	1.0	.99, 1.0	.21	.16	895	1.0	.98, 1.0	.19	.52	959	1.0	.98, 1.1	.206	.36
HGS [a]	1825	.98	.93, 1.0	.20	.44	882	.98	.92, 1.0	.18	.59	943	.97	.88, 1.1	.206	.47
SLJ [a]	1834	1.0	1.0, 1.0	.21	**.01**	886	1.0	1.0, 1.0	.20	**.00**	948	1.0	.99, 1.0	.210	.57
40mS [a]	926	.90	.77, 1.0	.22	.19	438	.82	.67, 1.0	.24	.06	488	.98	.75, 1.3	.214	.89
20mSRT [a]	1017	1.0	.99, 1.1	.18	.07	471	1.1	1.0, 1.2	.18	**.01**	546	.98	.89, 1.1	.181	.95

Stratified by Sex and Pubertal status

Males

Predictor	**Pre/Early Pubertal**					**Pubertal**				
	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*
FB [c]	296	.99	.95, 1.0	.25	.57	409	.96	.92, 1.0	.18	.08
SAR [c]	385	1.0	.96, 1.1	.23	.67	468	1.0	.97, 1.1	.17	.57
HGS [c]	384	.92	.83, 1.0	.24	.12	456	1.0	.92, 1.1	.16	.66
SLJ [c]	384	1.0	1.0, 1.0	.24	.11	459	1.0	1.0, 1.0	.19	**.02**
40mS [c]	164	.93	.67, 1.3	.30	.68	252	.75	.56, 1.0	.21	.05
20mSRT [c]	197	1.1	.99, 1.2	.25	.08	246	1.1	.97, 1.2	.15	.18

Females

Predictor	**Pre/Early Pubertal**					**Pubertal**				
	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*
FB [c]	360	.99	.93, 1.0	.28	.74	471	1.1	1.0, 1.1	.20	**.01**
SAR [c]	412	1.0	.99, 1.1	.28	.08	504	1.0	.95, 1.1	.20	.82
HGS [c]	406	1.0	.90, 1.2	.28	.58	495	.92	.81, 1.0	.20	.23
SLJ [c]	408	1.0	.99, 1.0	.29	.28	500	1.0	.99, 1.0	.21	.87
40mS [c]	190	.96	.63, 1.5	.29	.86	275	1.2	.78, 1.7	.25	.45
20mSRT [c]	237	1.0	.88, 1.2	.23	.75	279	.96	.82, 1.1	.25	.56

OR = Odds Ratio, 95% CI = 95% Confidence Interval, FB = Flamingo Balance, SAR = Backsaver Sit & Reach, HGS = Handgrip Strength, SLJ = Standing Long Jump, 40mS = 40-meter Sprint, 20mSRT = 20-meter Shuttle Run

[a] *Models adjusted for Age, Sex, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[b] *Models adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[c] *Models adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Valid Wear Time at T3*

6.4.3 Aim 3. Physical Activity, Fitness and Cognitive Function

Results from the cognitive function analyses are presented in **Tables 6.5 and 6.6**. All models did not show a substantial goodness of fit, however some fitness tests did statically significantly contribute to the models, although OR were less than or equal to 1. **Table 6.5** presents data from the linear regressions using WHO PA guidelines and fitness test performance at T0/T1 to predict cognitive inflexibility (preservative errors) at T3, measured by the Berg Card Sorting Task. Results indicated that meeting WHO guidelines at T0/T1 was not indicative of improved cognitive inflexibility (i.e., decreased preservative errors) and only decreased performance on the FB test (increased touchdowns) was associated with increased cognitive inflexibility (higher number of preservative errors). In the sex-stratified sample, decreased FB test performance was associated with increased cognitive inflexibility and increased 20mSRT performance was associated with improved cognitive inflexibility (i.e., decreased preservative errors) only in the male group. In the stratified samples by sex and T3 pubertal status, increased 20mSRT performance in the male pre/early pubertal group was associated with improved cognitive inflexibility (i.e., decreased preservative errors) and decreased FB test performance in the male pubertal group was associated with increased cognitive inflexibility. No associations were found in the female pre/early pubertal or pubertal groups.

The logistic regressions with adaptive decision-making ability measured by performance on the Hungry Donkey test are shown in **Table 6.6**. Results indicated that meeting WHO PA guidelines at T0/T1 and high performance on fitness tests did not predict a higher likelihood of an increased adaptive decision-making ability at T3 for the whole sample and the sex stratified sample. Decreased FB performance and increased SLJ performance in the male pubertal group were the only tests that were statistically significantly associated with increased likelihood of adaptive decision-making ability at T3 according to the *p* values, but the OR were equal to 1, indicating no statistical significance.

Table 6.5: Aim 3. Linear regressions of fitness and meeting WHO guidelines at baseline to predict cognitive inflexibility[1] at follow-up

	Whole Sample						Males [b]						Females [b]					
Predictor	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*
WHO [a]	2015	.25	.01	-.74, 1.2	.05	.62	998	.81	.05	-.41, 1.6	.06	.22	1017	-.47	-.02	-.95, 1.1	.03	.55
FB [a]	1772	.05	.06	.00, .10	.05	**.03**	835	.07	.08	.01, .13	.06	**.03**	937	.04	.04	-.04, .12	.03	.32
SAR [a]	1980	-.03	-.02	-.08, .02	.05	.29	979	.02	.01	-.05, .09	.06	.64	1001	-.07	-.06	-.15, .00	.04	.07
HGS [a]	1973	.05	.03	-.06, .17	.04	.36	975	.12	.06	-.03, .27	.06	.12	998	-.02	-.01	-.20, .17	.03	.87
SLJ [a]	1983	-.01	-.06	-.03, .00	.05	.06	980	-.01	-.05	-.03, .01	.06	.19	1003	-.02	-.06	-.04, .01	.04	.16
40mS [a]	943	.13	.03	-.22, .47	.02	.48	455	.14	.03	-.32, .60	.03	.55	488	.09	.02	-.45, .62	.02	.75
20mSRT [a]	961	-.06	-.03	-.20, .07	.03	.36	465	-.20	-.11	-.37, -.03	.06	**.02**	496	.09	.04	-.12, .31	-.01	.40

Stratified by Sex and Pubertal status

Males

	Pre/Early Pubertal						Pubertal					
Predictor	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*
WHO [c]	415	1.1	.06	-1.2, 3.4	.07	.34	546	.66	.04	-1.0, 2.3	.04	.44
FB [c]	327	.01	.01	-.09, .11	.06	.85	482	.11	.12	.02, .20	.05	**.02**
SAR [c]	404	-.01	-.01	-.13, .10	.06	.81	538	.02	.01	-.08, .11	.04	.72
HGS [c]	401	.12	.06	-.13, .37	.07	.34	538	.17	.09	-.04, .37	.04	.11
SLJ [c]	403	-.02	-.09	-.05, .01	.07	.16	540	.00	-.02	-.03, .02	.04	.72
40mS [c]	153	-.02	-.01	-.88, .83	.02	.93	288	.28	.07	-.30, .87	.02	.33
20mSRT [c]	183	-.41	-.21	-.70, -.11	.12	**.01**	264	-.11	-.06	-.33, .11	.02	.34

Females

	Pre/Early Pubertal						Pubertal					
Predictor	n	ß	B	95% CI	Adj R^2	*P*	n	ß	B	95% CI	Adj R^2	*P*
WHO [c]	413	-.91	-.04	-3.4, 1.6	.04	.48	568	-.21	-.01	-2.2, 1.8	.04	.84
FB [c]	365	.07	.06	-.06, .20	.03	.32	539	.01	.00	-.10, .11	.04	.91
SAR [c]	402	-.12	-.09	-.25, .01	.07	.07	563	-.05	-.04	-.14, .05	.03	.34
HGS [c]	404	-.10	-.04	-.42, .22	.04	.54	559	.03	.01	-.20, .26	.03	.78
SLJ [c]	407	-.02	-.09	-.06, .01	.05	.20	562	-.01	-.04	-.04, .02	.04	.48
40mS [c]	168	-.43	-.09	-1.4, .53	.06	.38	298	.20	.04	-.48, .89	.03	.56
20mSRT [c]	198	.06	.03	-.32, .44	.00	.74	275	.08	.04	-.19, .35	.03	.57

ß = Beta coefficient, B = Standardized Beta coefficient, 95% CI = 95% Confidence Interval, WHO = meeting WHO guidelines, "No" as reference, FB = Flamingo Balance, SAR = Backsaver Sit & Reach, HGS = Handgrip Strength, SLJ = Standing Long Jump, 40mS = 40-meter Sprint, 20mSRT = 20-meter Shuttle Run

[1] Cognitive inflexibility measured via number of preservative errors during the Berg Card Sorting Task

[a] *Models adjusted for Age, Sex, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[b] *Models adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[c] *Models adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Valid Wear Time at T3*

Table 6.6: Aim 3. Logistic regressions of fitness and meeting WHO guidelines at baseline to predict adaptive decision-making ability[1] at follow-up

	Whole Sample					Males [b]					Females [b]				
Predictor	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*
WHO [a]	2144	.76	.54, 1.1	.01	.12	1074	.77	.48, 1.2	.01	.28	1070	.69	.40, 1.2	.02	.18
FB [a]	1868	1.0	1.0, 1.0	.01	.16	885	1.0	.99, 1.0	.01	.21	983	1.0	.99, 1.0	.02	.20
SAR [a]	2105	1.0	.98, 1.0	.01	.74	1051	.99	.97, 1.0	.01	.63	1054	1.0	.98, 1.0	.02	.78
HGS [a]	2098	.99	.95, 1.0	.01	.75	1049	.98	.93, 1.0	.01	.48	1049	1.0	.95, 1.1	.02	.73
SLJ [a]	2109	1.0	.99, 1.0	.01	.69	1055	1.0	.99, 1.0	.01	.21	1054	1.0	1.0, 1.0	.02	.44
40mS [a]	980	1.0	.91, 1.2	.03	.58	480	.98	.83, 1.2	.06	.84	500	1.1	.89, 1.3	.05	.45
20mSRT [a]	999	1.0	.96, 1.1	.02	.62	491	1.0	.95, 1.1	.03	.78	508	1.0	.94, 1.1	.04	.64

Stratified by Sex and Pubertal status

Males

	Pre/Early Pubertal					Pubertal				
Predictor	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*
WHO [c]	456	.65	.29, 1.5	.04	.30	579	.94	.51, 1.7	.01	.84
FB [c]	352	.99	.96, 1.0	.04	.57	506	1.0	1.0, 1.1	.04	**.02**
SAR [c]	442	.98	.94, 1.0	.04	.22	570	1.0	.97, 1.0	.02	.74
HGS [c]	441	.98	.90, 1.1	.04	.61	570	.99	.92, 1.1	.01	.89
SLJ [c]	442	1.0	.99, 1.0	.04	.67	574	.99	.98, 1.0	.03	**.02**
40mS [c]	164	.63	.44, .86	.17	.44	300	1.2	.96, 1.5	.10	.10
20mSRT [c]	197	1.0	.94, 1.2	.09	.43	274	.98	.90, 1.1	.04	.60

Females

	Pre/Early Pubertal					Pubertal				
Predictor	n	OR	95% CI	R^2	*P*	n	OR	95% CI	R^2	*P*
WHO [c]	434	.80	.34, 1.9	.06	.63	598	.68	.33, 1.4	.03	.29
FB [c]	386	1.0	.98, 1.1	.08	.23	562	1.0	.97, 1.0	.03	.89
SAR [c]	422	1.0	.97, 1.1	.05	.40	594	.99	.96, 1.0	.03	.55
HGS [c]	424	.94	.84, 1.0	.08	.25	588	1.1	.99, 1.1	.04	.10
SLJ [c]	426	1.0	.99, 1.0	.06	.55	592	1.0	.99, 1.0	.03	.83
40mS [c]	169	1.4	1.0, 2.1	.12	.05	309	.94	.72, 1.2	.06	.65
20mSRT [c]	200	.96	.84, 1.1	.11	.61	285	1.0	.95, 1.2	.07	.34

95% CI = 95% Confidence Interval OR = Odds Ratio FB = Flamingo Balance, SAR = Backsaver Sit & Reach, HGS = Handgrip Strength, SLJ = Standing Long Jump, 40mS = 40-meter Sprint, 20mSRT = 20-meter Shuttle Run

[1] Adaptive decision-making ability was assessed by the Hungry Donkey test

[a] *Adjusted for Age, Sex, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[b] *Adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Pubertal Status, Valid Wear Time at T3*

[c] *Adjusted for Age, Country, ISCED, Income, BMI category, WHO guidelines met at Baseline*, *Gap, Valid Wear Time at T3*

6.5 Discussion

The current study aimed to examine the longitudinal associations between childhood physical fitness and physical activity, and physical activity and cognitive function during later childhood/early adolescence and how this association differed between males and females. Results indicated that baseline PA was a predictor of follow-up PA, certain physical fitness tests were associated with follow-up PA and baseline PA and physical fitness were not associated with follow-up cognitive function tests.

6.5.1 Baseline Physical Activity and Follow-Up PA

Results from this study support previous research that indicates PA behaviours can track over time (Jaakkola et al., 2019; Jones et al., 2013; Potter et al., 2018). Recently, Potter et al. (2018) found that PA time in children aged 4-5 years moderately tracked over a period of 3 years while Jaakkola et al. (2019) found that accelerometer-derived MVPA from 11-year-old children at Baseline was significantly associated with MVPA one year later. While these results are interesting, Potter et al. (2018) used a questionnaire to assess PA and did not collect information on PA intensity and Jaakkola et al. (2019) used a short follow-up period of just one year. Our results showed that meeting PA guidelines during T0/T1 was strongly associated with average time spent in MVPA and children who obtained greater than or equal to 60 minutes of MVPA at T0/T1 were more likely to do so an average of 5.1 (1.0) years later.

These associations were found for both sexes, however results differed when the sample was stratified by sex and pubertal status at T3. Meeting PA guidelines at T0/T1 remained a strong predictor of MVPA at T3 in males regardless of pubertal status, but it did not predict MVPA at T3 in females within the pubertal group. Additionally, males and females in the pre/early pubertal groups who met PA guidelines at T0/T1 were more likely to meet guidelines at T3, but this was not true for males and females in the pubertal groups. One possible explanation for this finding is that PA does not track over time but rather it declines during adolescence. Research supports this idea as numerous studies have shown that PA declines from childhood to adolescence (Corder et al., 2015; Dumith et al., 2011; Haas et al., 2021) and that PA declines more rapidly in girls than boys (Corder et al., 2010; Dumith et al., 2011; Okely et al., 2017). Consequently, results from the most recent Health Behaviour in School-aged Children (HBSC) survey in Europe and Canada suggest that PA levels are consistently lower in girls compared to boys at all ages, and that the decline in PA during adolescence is steeper in boys compared to girls (Inchley et al., 2020). However, PA estimates were derived from self-reported questionnaires for this survey. Findings from Farooq et al. (2018) suggest that PA does not start declining during adolescence, but rather propose that PA is *already* declining by the time children reach school-age. Therefore, another possible explanation of our findings is that PA levels were the highest at T0/T1 in the pre/early pubertal groups and remained high enough to meet guidelines for children who stayed in the pre/early pubertal groups. For children who transitioned through puberty between T0/T1 and T3, or who had already reached puberty at T0/T1, their levels of PA had been declining for years meaning they may have had enough PA to marginally meet PA guidelines at T0/T1 but due to continued declines in PA, they did not acquire enough MVPA to meet guidelines at T3. Previous studies did not account for pubertal status in their analyses (Corder et al., 2015; Farooq et al., 2018), therefore the role of puberty in the change of PA from childhood to adolescence should be further investigated. Furthermore, pubertal status should be considered during design intervention and additional consideration should be given to strategies or developmental theories concerning PA in pubertal females. Whether PA tracks over time or PA beings to decline at a young age, the findings from our study have important implications for future interventions and emphasize the importance of targeting PA habits during early childhood.

6.5.2 Baseline Physical Fitness and Follow-Up PA

Results from our statistical analyses involving fitness tests performed T0/T1 showed that better performance on the SLJ, 40mS and the 20mSRT were associated with increased MVPA at T3 and increased SLJ performance was statistically significantly associated with meeting PA guidelines at T3. Although the OR for this association was equal to 1, the information gained from the regression analyses indicates that SLJ is associated with increased MVPA at follow-up and therefore SLJ performance may be an important contributor for meeting PA guidelines at baseline. The results are concurrent with findings from Jaakkola et al. (2016) who found that physical fitness in a sample for 12-year-olds was longitudinally associated with PA six years later, however they used a composite score for fitness and PA was assessed via a questionnaire in their analyses.

Our results from the sex stratified sample showed that associations between fitness at T0/T1 and MVPA or meeting guidelines at T3 differed between males and females. In the male group, increased SLJ, 40mS and 20mSRT (cardio-respiratory fitness) performance were associated with increased MVPA at T3. Associations between SLJ and 40mS, and meeting WHO guidelines at T3 were statistically significant, however the odds of meeting guidelines were not increased for those with higher test performance. For all female participants and pubertal females, only their performance on the FB test was associated with MVPA at T3, however the direction of this association indicated that increased number of touchdowns (decreased balance) was associated with increased MVPA. More research is needed to clarify this association and additional measures of balance (static and dynamic) should be examined. Furthermore, it remains unclear why performance on other fitness tests (SLJ, 40mS and 20mSRT) were associated with follow-up PA in males and not females. Future research is needed to elucidate the mechanisms behind the observed sex differences in associations between specific fitness tests and PA.

Previous research has found sex differences in the associations between fitness and PA; Huotari et al. (2011) showed that increased fitness levels during adolescence predicted higher PA engagement during adulthood in males and not females. Additionally, Jaakkola et al. (2019) found that cardiorespiratory fitness as measured by the 20mSRT, was longitudinally associated with MVPA in boys and not girls, although participants were, on average, older at baseline (11.36 years compared to our average of 7.5 years). In the sex and pubertal status stratified groups, fitness tests were only statistically significantly associated with meeting guidelines in the pubertal groups. This could potentially be explained by the increased strength of the relationship between fitness and physical activity during middle to late childhood as postulated by Stodden et al. (2008). However the variation in growth and maturation during adolescence makes it difficult to fully comprehend the association between fitness measures and PA (Armstrong, 2013)

6.5.3 Physical Activity, Fitness and Cognitive Function analyses

Our findings indicated that PA and physical fitness were not associated with cognitive function test performance as our models did not show a substantial goodness of fit, indicating that PA and physical fitness during T0/T1 were not associated with cognitive inflexibility or adaptive decision-making ability at T3. These results are not concurrent with other findings as previous reviews have found positive associations between physical activity and cognitive functioning in children (Donnelly et al., 2016; Lees & Hopkins, 2013; Sibley & Etnier, 2003), although many different methods have been used for the assessment of cognitive function in children which may limit comparability across studies.

Results from our cognitive inflexibility analyses showed that decreased FB test performance (i.e., higher number of touchdowns) was associated with increased cognitive inflexibility (increased preservative errors) in the whole sample, the male group, and the pubertal female group. An additional association was found in the male group and the male pre/early pubertal group which indicated that increased cardiorespiratory fitness as assessed by the 20mSRT was associated with decreased cognitive inflexibility (i.e., increased cognitive flexibility). Previous results have shown that higher participation in organized sport was cross-sectionally associated with increased set shifting as measured during a similar card sorting task (McNeill et al., 2018), and that aerobic fitness as dynamic balance were longitudinally associated with increased measures of Executive Function after a 9 month follow-up period (Niederer et al., 2011). However, both of those studies were conducted in preschoolers, and therefore additional longitudinal studies are needed to fully explore the associations between PA, physical fitness, and cognitive functioning.

The adaptive decision-making ability analyses revealed no statistically significant associations between PA or physical fitness and increased likelihood of having an adaptive decision-making ability at T3. However, performance on the FB test and SLJ was statistically significantly associated with adaptive decision-making ability for pubertal females. A previous cross-sectional study found that performance on the Hungry Donkey test was lowest in 12 to 13 year olds compared to children aged to 8 - 11 years and 14 – 17 years (Cortes-Patino et al., 2017). As the mean age of our sample was 12.6 years at Follow-up, the lack of an association between PA, physical fitness and adaptive decision-making ability may have been caused by general poor task performance associated with this age group. Additionally, a previous review suggested that movement is more important for cognitive function rather than the intensity (Sibley & Etnier, 2003), therefore future studies should continue to investigate the association between all types of physical activities and measures of cognitive function such as adaptive-decision making abilities in children.

6.5.4 Strengths and Limitations

Although thus study has some major strengths such as a relatively large sample size, a longitudinal study design with a long follow-up period and the use of accelerometers to obtain objective measures of physical activity, some limitations should be mentioned. The first limitation is that we did not collect physical fitness data at T3, preventing us from examining the bidirectionality of the relationship between physical activity and physical fitness over time. Subsequently, we did not collect Baseline measures of cognitive function which prevented us from examining associations between PA, fitness, and the change in cognitive functioning. However both the Hungry Donkey Test (Crone & van der Molen, 2004) and the Berg Card sorting Task (Heaton et al., 1993), have only been used in children as young as 6 years, therefore it is unclear if these tests are appropriate for children of a younger age. An additionally limitation is that although our study design incorporated a large timeframe between T0/T1 and T3, more follow-ups with shorter time intervals may have provided more insight into the effect of puberty on the relationship between PA and fitness with follow-up PA. Furthermore, we did not include measures of pubertal status at T0/T1, and therefore future studies should analyze the effect of the transition through puberty on the association between fitness and PA. Finally, future research should examine the types of physical activities regularly engaged in by males and female children and how sports participation varies with sex and development (e.g., pubertal status).

6.6 Conclusions

To conclude, this study found that children meeting WHO guidelines for PA of greater than or equal to 60 minutes of MVPA per day at baseline, was associated with MVPA and higher likelihood of meeting those guidelines at follow up. Additionally, some fitness tests such as Standing Long Jump, Flamingo balance test, 40-meter sprint and 20-meter Shuttle Run test of cardiorespiratory fitness were longitudinally associated with MVPA, and meeting PA guidelines and these associations varied with sex and pubertal status. Results from the present study emphasize the critical importance of engaging children in PA during early childhood to increase the likelihood of sustained PA engagement later in life and that habitual physical activity should be supported by structured physical activities (e.g., during daycare facilities, schools, sport clubs) to strengthen children’s fitness.

6.7 Supplementary Material

Supplementary Table 6.7: Detailed description of Physical Fitness Testing Protocols

Physical Fitness Test	Ability assessed	Testing Protocol
Flamingo Balance (FB)	single leg balance	• Children stood on one foot, bent free leg backwards and held their foot. • Children were instructed to maintain position for 1 minute • Each child was given one practice trial. • The number of attempts needed to stand on one leg for one full minute was recorded • Children were excluded if they touched down >15 times within the first 30 seconds. • Score = sum of attempts on both legs; lower scores indicate better performance.
Backsaver Sit & Reach (SAR)	hamstring flexibility	• Testing required a standard box with a scale on top, each leg was assessed separately. • Children sat with their testing leg straight, foot flat against the box, while the other leg was relaxed in a bent position and slowly reach as far forward as possible. • Children had 2 attempts per leg, the furthest distance reached was recorded for each leg. • Score = avg max distance reached of both legs; higher scores indicate better performance.
Handgrip Strength (HS)	maximal upper body isometric force production	• Children stood with both feet shoulder width apart and extend arms by their side. • Holding a dynamometer (TKK 5101; Takei, Tokyo, Japan), children were told to squeeze as hard as possible, without letting the dynamometer touch any part of their body. • Dynamometers were adjusted for sex and hand size for each child (Ruiz et al., 2006). • The scale started at 5 kg, to children who did not reach this were given a score of 2.5 kg • The test was performed twice per hand, and the highest score per hand was recorded. H • Score = avg of right and left handgrip strength; higher scores indicate better performance.
Standing Long Jump (SJL)	lower limb explosive strength	• Children jumped as far as possible without falling and land with both feet together. • Attempts were invalid if the child touched the ground with their hands upon landing. • Distance was measured from the point of take-off to the back of the most posterior heel. • Two attempts were given • Score = furthest distance jumped (cm). Higher scores indicate better performance.

40-meter Sprint (40mS)	maximum running speed	• 40 meters was marked off by 5 cones placed 10-meters apart. A running lane was created by placing another row of 5 cones, 3 meters apart from the first row of marker cones. • Children were instructed to run as fast as possible upon a starting signal. The test was performed twice, • Score = fastest time; lower scores indicate better performance.

20-meter Shuttle-Run (20mSRT)	cardio-respiratory fitness
	
	(VO2 Max)
		• Children were instructed to run back-and-forth between two lines that were 20 meters apart while matching their pace to a recording of beep signals.
		• The child continued to run until reaching fatigue or failing to reach the line before the beep on two consecutive occasions.
		• Protocols were unified using the Leger protocol to estimate VO2 max
		
		Unification of Protocols:
		
		• 4 different versions of this test were applied during field assessments. The *Multistage fitness test* (sports coach UK) was applied in Germany, Estonia and Cyprus; the *Leger test* (CAEP Quebec Faca) was applied in Spain and Hungary, the *Multistage fitness test* was applied in Sweden and the *Uithouding Shuttle run test* was conducted in Belgium.
		• The Leger protocol (Leger et al., 1988) was used to unify results.
		    o initial speed for the Leger test (8.5 km/h) and increases in increments of 0.5 km/h for each auditory *beep* cue;
		    o this rate of change between the auditory cues was used to estimate the number of shuttles ‘beeps’ completed by a child for the other three protocols.
		    o This information was then converted to stages and, using the Leger equation (Leger et al., 1988), stages were used to estimate maximal oxygen consumption (VO2max); the greater the number of shuttles completed indicates better performance.
		    o For analyses including the 20mSRT, participants from Italy and Hungary were excluded; Italian centres did not administer this test and shuttles were counted differently in Hungary and could not be reconciled using our analysis approach.

Supplementary Table 6.8: Detailed description of Cognitive Function Testing Protocols

Cognitive Function Test	Measures	Testing Protocol
Hungry Donkey **(Adapted from Iowa Gambling Task)**	decision making ability	• In 100 trials, children had to help a hungry donkey get as many apples as possible by choosing one of 4 doors presented on the screen. • Each choice resulted in a reward; the donkey was given a certain number of apples. • Some choices resulted in punishment meaning apples were taken from the donkey. • Doors 1 and 2 resulted in larger immediate rewards but ultimately resulted in more apples being taken away, as such they were classified as disadvantageous doors. • Doors 3 and 4 results in smaller amounts of apples being rewarded but resulted in a larger number of apples in the long run and were classified as advantageous doors. • Decision making ability = # of advantageous choices - # of disadvantageous choices • "yes" = adaptive decision-making ability (more advantageous doors) • "no" = no adaptive decision-making ability (more disadvantageous doors)
Berg Card Sorting Task **(Also referred to as the Wisconsin Card Sorting Test)**	cognitive inflexibility	• Children sorted 4 cards with different colours and symbols according to a particular unknown rule • Feedback ("correct"/ "incorrect") given after sorting each card to help the child discover the rule. • The rule was changed without notice every time 10 cards consecutively correctly, leaving the child to discover the 'new' rule. • Once the rule was changed, the number of cards sorted according to the previous rule was counted. • Preservative errors = number of cards sorting according to previous rule after new rule implemented • Measure of cognitive inflexibility, a higher number of preservative errors indicates more cognitive inflexibility

Chapter 7. Dissertation Progress Summary 2

7.1 Key Findings

A summary of research questions, study objectives and results for Studies 3 and 4 are presented in **Figure 7.1.**

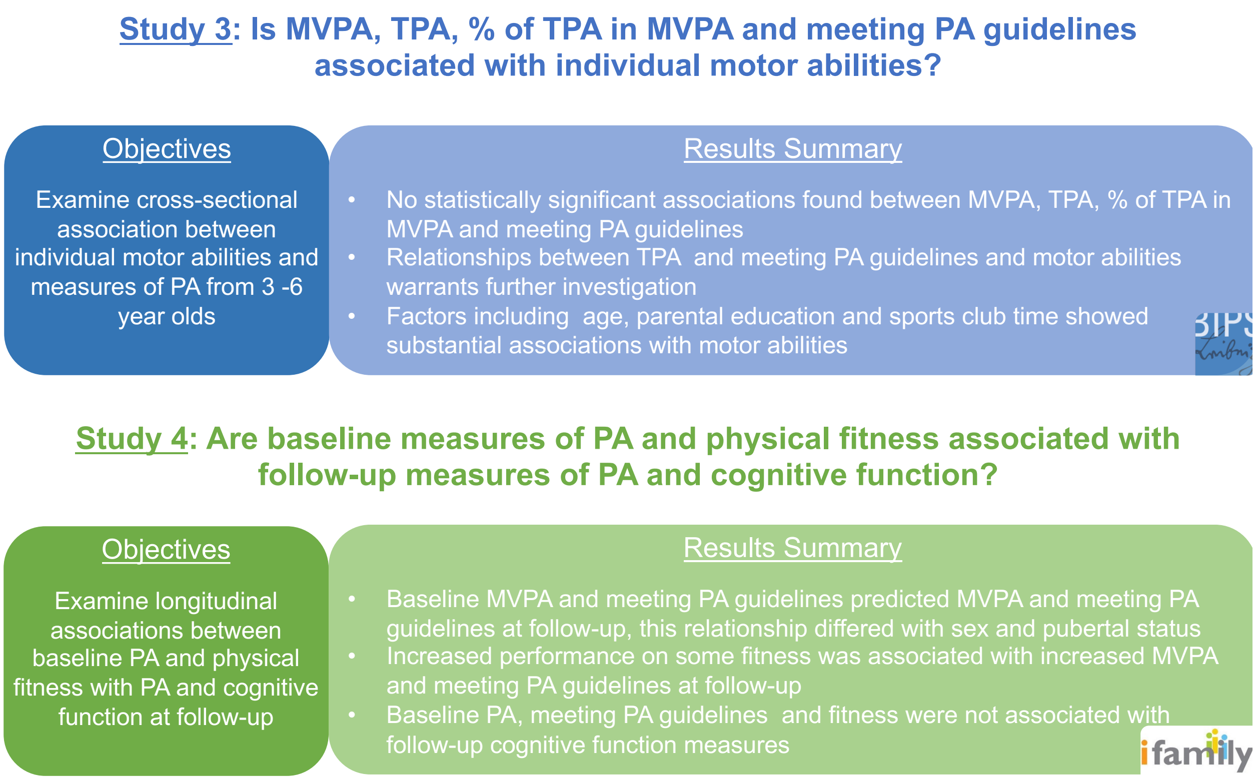


Figure 7.1: Outline of research questions, objectives, and summary of results from Studies 3 and 4.

7.1.1 Study 3

Findings for Study 3 are summarized in Figure 7.1. The association between four different measures of physical activity with five individual motor ability tests in preschool-aged children was examined. Results showed no significant associations between any of the physical activity metrics and performance on motor ability tests.

Although associations did not reach statistical significance, the directionality and tendencies of associations combined with the strength of certain models suggest that further examination is warranted into associations between TPA and meeting PA guidelines in preschool-aged children. Findings from this study demonstrated that other factors such as age, time spent at a sports club and parental education showed strong associations with motor abilities in our sample. Subsequently, specific types of activities (i.e., those performed at a sports club) may have a greater influence on motor ability and thus development of fundamental movement skills, compared to the quantity of physical activity. Future studies should explore the relationship between specific activities and motor abilities by comparing children with and without sports club memberships as well as children who participate in organized sports during the early years compared to those who do not. Additionally, tests that assess the quality of motor ability or fundamental movement skill performance could provide more insight into the relationship between motor competence and PA. Longitudinal observations of these associations may provide insight into why certain children have better motor abilities and subsequent motor competency compared to others, while providing important information for future interventions and policy development (i.e., physical education curriculum).

7.1.2 Study 4

In Study 4, the longitudinal associations between PA, physical fitness, and cognitive function in a large cohort of children were examined. All associations were conducted for the entire sample, the sex-stratified sample, and the sample stratified by sex and pubertal status at follow-up to provide insight into how these associations differed between males and females before and after puberty. Key findings from this study are summarized in Figure 7.1.

Results for Aim 1; examining whether PA measures at baseline were associated with PA at follow-up, suggest that PA behaviours track over time as children who met PA guidelines at baseline had increased levels of MVPA and were also more likely to meet PA guidelines at follow-up. Interestingly this association was found in the entire sample and the sex-stratified sample but differed when the sample was stratified by pubertal status and sex. Meeting PA guidelines at baseline was associated with increased levels of MVPA and increased likelihood of meeting PA guidelines at follow-up for the male and female pre/early pubertal groups, but not in the pubertal groups. Meeting guidelines at baseline was only associated with increased levels of MVPA in pubertal boys, however future studies should continue to examine associations between baseline and follow-up measures of PA during puberty with larger sample sizes. This longitudinal analysis highlights the importance of interventions targeting PA behaviours throughout childhood and adolescence, particularly in females.

Analyses examining the associations between physical fitness and PA (Aim 2) indicated that fitness tests such as the Standing Long Jump (SLJ), Flamingo Balance (FB), 40-meter Sprint (40mS) and cardiorespiratory fitness as measured by the 20-meter Shuttle Run test (20mSRT) may be associated with higher levels of MVPA at follow-up. Results implied that the importance of physical fitness components may vary depending on sex. Future studies should continue to investigate the longitudinal relationship between physical fitness, including its' underlying motor abilities, and physical activity to determine potential mechanisms of these observed sex differences.

Results from the cognitive function analyses (Aim 3) suggested that meeting PA guidelines and physical fitness test performance were not associated with cognitive function at follow-up. Findings suggest that the relationship between certain fitness tests (FB and 20mSRT) and cognitive functioning should be further explored. Future studies should investigate associations between other intensities of movement such as sedentary behaviour and light physical activity, and additional measures of cognitive function to examine if other movement behaviours are related to a wider variety of cognitive function constructs. Additionally, studies should examine the change in cognitive function from early childhood to adolescence and how this may be associated with the change in movement behaviours during this critical developmental period.

Study 4 presents important results that provide insight into the longitudinal associations between multiple indicators of health from a large, multinational sample. Results provide further support for investigation of the complex relationships between physical activity, physical fitness, and cognitive function and how these associations differ between males and females before and after puberty.

Chapter 8. General Discussion

8.1 Summary of research aims

This dissertation aimed to highlight the different methodologies currently used to collect and analyse accelerometer data acquired from young children and to examine the implications of different processing methods on physical activity and sedentary behaviour outcomes. A secondary aim was to gain further insight into the relationships between physical activity and motor abilities, physical fitness, and cognitive function in young children. For **Study 1**, an extensive scoping review was conducted to examine the data collection and processing methods reportedly used by scientists and clinicians over the past eleven and a half years (2009-2021) to quantify young children's movement behaviours via accelerometry. This study resulted in a comprehensive list of recommended reporting practices for researchers to consider when designing study protocols for measuring movement behaviours in young children. The effect of applying different cutpoints to young children's accelerometry data was examined in **Study 2.** It was hypothesized that applying different cutpoints would significantly impact accelerometer outputs which would, in turn, result in a significant change in the number of children classified as meeting the Canadian guidelines for physical activity. The last set of studies (**Studies 3 and 4**) investigated the cross-sectional associations between young childrens' physical activity and individual motor abilities (**Study 3**) and the longitudinal associations between physical activity, fitness, and cognitive function (**Study 4**). It was hypothesized that children with increased levels of physical activity would have increased performance on key motor abilities (**Study 3**) and that young children with increased physical fitness test performance and physical activity at baseline would have increased physical activity levels and cognitive function at follow-up several years later (**Study 4**).

8.2 Integrated impact of findings

Results from Studies 1 and 2 demonstrate the large variability in current methods used to obtain and analyse accelerometer data obtained from young children, and that certain choices (i.e. cutpoints) can drastically affect outcome measures such as time spent in sedentary behaviour, light physical activity and moderate to vigorous physical activity. Inconsistencies in methodologies used to analyse movement behaviours in young children has been reviewed previously (Bruijns et al., 2020; Cain et al., 2013b; Migueles et al., 2017), but reviews have mainly focused on studies using specific devices, were limited to specific age ranges and did not thoroughly report on the settings in which studies were conducted (i.e. free-living vs preschool/childcare). The inclusion of studies using a wide variety of accelerometers in sample populations with large age ranges that included young children and studies conducted across multiple settings, ensures that Study 1 provides an extensive overview of methods being used to collect and process accelerometer data in young children.

Of the methodologies reviewed, the reporting of cutpoints showed extensive variability due to the large selection of cutpoints available for quantifying accelerometer outputs into movement intensities, a phenomenon that has been termed “cutpoint non-equivalence” (CNE) (Bornstein et al., 2011). Study 2 demonstrated the impacts of CNE as results showed that choice of cutpoint resulted in significantly different amounts of SED, LPA and MVPA. Previous studies have shown similar results (Costa et al., 2014; Leeger-Aschmann et al., 2019; van Cauwenberghe, 2011), but only examined a small number of cutpoints, did not observe differences in all movement intensities and focused on data from populations of narrower age ranges such as 2 – 3 year olds (Costa et al., 2014), 3 – 5 year olds (Bornstein et al., 2011; Leeger-Aschmann et al., 2019) or 5 – 6 year olds (van Cauwenberghe, 2011). Additionally, previous studies have applied cutpoints developed using a specific age range to accelerometer data acquired from children outside of this age range (Gutierrez-Hervas et al., 2020; Määttä et al., 2020), which had unknown implications for determining if a child met age-appropriate PA recommendations. However, results from Study 2 showed that even when cutpoints developed for a specific age range were only applied to the portion of our sample within that age range, all cutpoints resulted in significantly different values for SED, LPA and

MVPA as well as significantly different portions of the sample categorized as meeting PA guidelines.

Studies 1 and 2 demonstrate the immediate need for more detailed reporting practices and more consistent methods for quantifying children's accelerometer data into different movement intensities. Ensuring that we have accurate and consistent measures of movement behaviours in this population is important given that the current guidelines for PA during early childhood in Canada (Tremblay et al., 2017) and globally by the World Health Organization (World Health Organization, 2019) are based on specific amounts of certain movement intensities. Many studies have examined relationships between measures of PA and certain health outcomes in children (Ekelund, 2012; Nilsen et al., 2020; Ricardo et al., 2019; Timmons et al., 2012), and the association between meeting PA guidelines and health outcomes (Carson et al., 2019; Guan et al., 2020; Nicolai Ré et al., 2020; Poitras et al., 2016), however there is limited information regarding how meeting these guidelines is associated with health outcomes in young children.

Results from Studies 3 and 4 suggest that the relationship between meeting PA guidelines and motor abilities should be further explored (Study 3),and that certain components of physical fitness and meeting PA guidelines during early childhood significantly increases the likelihood of meeting PA guidelines during later childhood/adolescence (Study 4). These findings are concurrent with previous studies indicating PA behaviours track overt time (Jaakkola et al., 2019; Jones et al., 2013; Potter et al., 2018). However, further analyses in Study 4 highlighted that the association between meeting movement guidelines at baseline and at follow-up is only true prior to puberty, especially for females. These results suggest that PA may decline during adolescence as suggested previously (Dumith et al., 2011), or perhaps that PA is already declining in school aged children as proposed by Farooq et al. (2018), meaning that by the time children reach puberty, their PA engagement has dropped to levels below recommended in guidelines. Despite the uncertainty of the timing of decline in PA, it is evident that movement behaviours should be targeted in young children to ensure that healthy PA behaviours are established early in life with the hope that these continue later into life.

8.3 Future Directions

Findings from this thesis provide numerous directions for future research. Future reviews should continue to examine the reporting of methods used to analyse accelerometer data obtained from young children; the peer-review and editorial process could be modified to include reporting checklists to assist them in their important role of ensuring that researchers are held accountable for the reporting of this important information. A major area in need of improvement in this field of research is regarding the use of cutpoints. Collectively, we are aware of the cutpoint non-equivalence issue and the impact this has on the interpretation of accelerometer output and subsequent examination of the relationship between movement and health. Therefore, future research should focus on reaching a consensus on the best way to quantify movement behaviours in young children. Other forms of accelerometer outputs such as raw acceleration have become a recent focus, although processing of this data is not without its own set of challenges. Due to the complex filtering, coding, and processing techniques associated with raw accelerometer data, extensive variability also exists in the methods used to analyse and interpret raw accelerometer outputs. Researchers should continue to build upon work using raw acceleration data, developing large data sets with open access, and incorporating experts from multiple areas (engineering, computer science, biomechanics, physiologists, clinicians) to determine more valid and repeatable methods for quantifying acceleration data into clinically meaningful outcomes. Physical activity guidelines are an important educational tool for parents and teachers and commonly inform clinicians/researchers of associations between health outcomes and specified amounts of movement behaviours in young children. Thus, these guidelines will most likely remain a key component in movement science research to quantify PA into specific movement intensities; a collective consensus from top movement researchers, although challenging to develop, could result in significant improvements in this field of scientific research.

8.4 Conclusions

Hundreds of researchers around the world are currently using accelerometers to capture movement behaviours in young children. These scientists use a wide variety of collection and processing methods, which renders the comparison and interpretation of results between studies extremely difficult. Choosing different methods to quantify accelerometer data into specific movement intensities has important implications on the amount of time children spend in different movement behaviours as well as the proportion of children meeting physical activity guidelines. Meeting physical activity guidelines is an important benchmark that can be used to track physical activity over time or examine how physical activity is associated with other health outcomes. Thus, it is imperative that the methods used to determine whether children are acquiring recommended levels of physical activity are thoroughly detailed so that any interpretation of these associations can come from an accurately informed point of view.

REFERENCES OR BIBLIOGRAPHY

ActiGraph. (2012). Actilife 6 user's manual [User's Manual]. *SFT12DOC13*, 1-89.

ActiGraph. (2018). *Low frequency extension explained*. https:// actigraphcorp.force.com/support/s/article/Low-Frequency-Extension- Explained.

ActiGraph. (2019). Actigraph wgt3x-bt + actilife user guide [User Guide]. *2*, 1-16.

Ahrens, W., Bammann, K., & Pigeot, I. (2019). The idefics/i.Family studies: Design and methods of a large european child cohort. In K. Bammann, L. Lissner, I. Pigeot, & W. Ahrens (Eds.), *Instruments for health surveys in children and adolescents* (pp. 1-24). Springer International Publishing. https://doi.org/10.1007/978-3-319-98857-3_1

Ahrens, W., Bammann, K., Siani, A., Buchecker, K., De Henauw, S., Iacoviello, L., Hebestreit, A., Krogh, V., Lissner, L., Marild, S., Molnar, D., Moreno, L. A., Pitsiladis, Y. P., Reisch, L., Tornaritis, M., Veidebaum, T., Pigeot, I., & Consortium, I. (2011). The idefics cohort: Design, characteristics and participation in the baseline survey. *Int J Obes (Lond), 35 Suppl 1*, S3-15. https://doi.org/10.1038/ijo.2011.30

Ahrens, W., Pigeot, I., Pohlabeln, H., De Henauw, S., Lissner, L., Molnar, D., Moreno, L. A., Tornaritis, M., Veidebaum, T., Siani, A., & consortium, I. (2014). Prevalence of overweight and obesity in european children below the age of 10. *Int J Obes (Lond), 38 Suppl 2*, S99-107. https://doi.org/10.1038/ijo.2014.140

Ahrens, W., Siani, A., Adan, R., De Henauw, S., Eiben, G., Gwozdz, W., Hebestreit, A., Hunsberger, M., Kaprio, J., Krogh, V., Lissner, L., Molnar, D., Moreno, L. A., Page, A., Pico, C., Reisch, L., Smith, R. M., Tornaritis, M., Veidebaum, T., Williams, G., Pohlabeln, H., Pigeot, I., & consortium, I. F. (2017). Cohort profile: The transition from childhood to adolescence in european children-how i.Family extends the idefics cohort. *Int J Epidemiol, 46*(5), 1394-1395j. https://doi.org/10.1093/ije/dyw317

Armstrong, N. (2013). Aerobic fitness and physical activity in children. *Pediatr Exerc Sci, 25*(4), 548 - 560.

Artero, E. G., Espana-Romero, V., Castro-Pinero, J., Ortega, F. B., Suni, J., Castillo-Garzon, M. J., & Ruiz, J. R. (2011). Reliability of field-based fitness tests in youth. *Int J Sports Med, 32*(3), 159-169. https://doi.org/10.1055/s-0030-1268488

Aubert, S., Barnes, J. D., Abdeta, C., Abi Nader, P., Adeniyi, A. F., Aguilar-Farias, N., Andrade Tenesaca, D. S., Bhawra, J., Brazo-Sayavera, J., Cardon, G., Chang, C. K., Delisle Nystrom, C., Demetriou, Y., Draper, C. E., Edwards, L., Emeljanovas, A., Gaba, A., Galaviz, K. I., Gonzalez, S. A., Herrera-Cuenca, M., Huang, W. Y., Ibrahim, I. A. E., Jurimae, J., Kamppi, K., Katapally, T. R., Katewongsa, P., Katzmarzyk, P. T., Khan, A., Korcz, A., Kim, Y. S., Lambert, E., Lee, E. Y., Lof, M., Loney, T., Lopez-Taylor, J., Liu, Y., Makaza, D., Manyanga, T., Mileva, B., Morrison, S. A., Mota, J., Nyawornota, V. K., Ocansey, R., Reilly, J. J., Roman-Vinas, B., Silva, D. A. S., Saonuam, P., Scriven, J., Seghers, J., Schranz, N., Skovgaard, T., Smith, M., Standage, M., Starc, G., Stratton, G., Subedi, N., Takken, T., Tammelin, T., Tanaka, C., Thivel, D., Tladi, D., Tyler, R., Uddin, R., Williams, A., Wong, S. H. S., Wu, C. L., Zembura, P., & Tremblay, M. S. (2018). Global matrix 3.0 physical activity report card grades for children and youth: Results and analysis from 49 countries. *J Phys Act Health, 15*(S2), S251-S273. https://doi.org/10.1123/jpah.2018-0472

Bailey, R. C., Olson, J., Pepper, S. L., Porszasz, J., Barstow, T. J., & Cooper, D. M. (1995). The level and tempo of children's physical activities: An observational study. *Med Sci Sports Exerc, 27*(7), 1033-1041.

Bammann, K., Sioen, I., Huybrechts, I., Casajus, J. A., Vicente-Rodriguez, G., Cuthill, R., Konstabel, K., Tubic, B., Wawro, N., Rayson, M., Westerterp, K., Marild, S., Pitsiladis, Y. P., Reilly, J. J., Moreno, L. A., De Henauw, S., & Consortium, I. (2011). The idefics validation study on field methods for assessing physical activity and body composition in children: Design and data collection. *Int J Obes (Lond), 35 Suppl 1*, S79-87. https://doi.org/10.1038/ijo.2011.38

Barnett, L. M., Lai, S. K., Veldman, S. L. C., Hardy, L. L., Cliff, D. P., Morgan, P. J., Zask, A., Lubans, D. R., Shultz, S. P., Ridgers, N. D., Rush, E., Brown, H. L., & Okely, A. D. (2016a). Correlates of gross motor competence in children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 46*(11), 1663-1688. https://doi.org/10.1007/s40279-016-0495-z

Barnett, L. M., Ridgers, N. D., Hesketh, K., & Salmon, J. (2017). Setting them up for lifetime activity: Play competence perceptions and physical activity in young children. *Journal of Science & Medicine in Sport, 20*(9), 856-860. https://doi.org/10.1016/j.jsams.2017.03.003

Barnett, L. M., Salmon, J., & Hesketh, K. D. (2016b). More active pre-school children have better motor competence at school starting age: An observational cohort study. *BMC Public Health, 16*(1), 1068. https://doi.org/10.1186/s12889-016-3742-1

Bechara, A., Tranel, D., & Damasio, H. (2000). Characterization of the decision-making deficit of patient with ventromedial prefrontal cortex lesions. *Brain, 123*, 2189 - 2202.

Berg, E. A. (1948). A simple objective technique for measuring flexibility in thinking. *Journal of General Psychology, 39*, 15-22. https://doi.org/10.1080/00221309.1948.9918159

Biddle, S. J. H., Ciaccioni, S., Thomas, G., & Vergeer, I. (2019). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. *Psychology of Sport and Exercise, 42*, 146-155. https://doi.org/10.1016/j.psychsport.2018.08.011

Bidzan-Bluma, I., & Lipowska, M. (2018). Physical activity and cognitive functioning of children: A systematic review. *Int J Environ Res Public Health, 15*(4). https://doi.org/10.3390/ijerph15040800

Birnbaum, J., Geyer, C., Kirchberg, F., Manios, Y., & Koletzko, B. (2016). Effects of a kindergarten-based, family-involved intervention on motor performance ability in 3- to 6-year-old children: The toybox-study. *Journal of Sports Sciences, 35*(4), 377-384. https://doi.org/10.1080/02640414.2016.1166390

Bornstein, D. B., Beets, M. W., Byun, W., Welk, G., Bottai, M., Dowda, M., & Pate, R. (2011). Equating accelerometer estimates of moderate-to-vigorous physical activity: In search of the rosetta stone. *J Sci Med Sport, 14*(5), 404-410. https://doi.org/10.1016/j.jsams.2011.03.013

Brandes, M., Steenbock, B., & Wirsik, N. (2018). Energy cost of common physical activities in preschoolers. *Journal of Physical Activity and Health, 15*(4), 233-238. https://doi.org/10.1123/jpah.2017-0348

Branta, C., Haubenstricker, J., & Seefeldt, V. (1984). Age changes in motor skills during childhood and adolescence. *Exerc Sport Sci Rev, 12*, 467-520.

Brazendale, K., Beets, M. W., Bornstein, D. B., Moore, J. B., Pate, R. R., Weaver, R. G., Falck, R. S., Chandler, J. L., Andersen, L. B., Anderssen, S. A., Cardon, G., Cooper, A., Davey, R., Froberg, K., Hallal, P. C., Janz, K. F., Kordas, K., Kriemler, S., Puder, J. J., Reilly, J. J., Salmon, J., Sardinha, L. B., Timperio, A., van Sluijs, E. M. F., & International Children's Accelerometry Database, C. (2016). Equating accelerometer estimates among youth: The rosetta stone 2. *J Sci Med Sport, 19*(3), 242-249. https://doi.org/10.1016/j.jsams.2015.02.006

Brond, J. C., & Arvidsson, D. (2016). Sampling frequency affects the processing of actigraph raw acceleration data to activity counts. *J Appl Physiol (1985), 120*(3), 362-369. https://doi.org/10.1152/japplphysiol.00628.2015

Bruijns, B. A., Truelove, S., Johnson, A. M., Gilliland, J., & Tucker, P. (2020). Infants' and toddlers' physical activity and sedentary time as measured by accelerometry: A systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1), Article 14. https://doi.org/10.1186/s12966-020-0912-4

Burchartz, A., Anedda, B., Auerswald, T., Giurgiu, M., Hill, H., Ketelhut, S., Kolb, S., Mall, C., Manz, K., Nigg, C. R., Reichert, M., Sprengeler, O., Wunsch, K., & Matthews, C. E. (2020). Assessing physical behavior through accelerometry - state of the science, best practices and future directions. *Psychol Sport Exerc, 49*, Article 101703. https://doi.org/10.1016/j.psychsport.2020.101703

Burgi, F., Meyer, U., Granacher, U., Schindler, C., Marques-Vidal, P., Kriemler, S., & Puder, J. J. (2011). Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: A cross-sectional and longitudinal study (ballabeina). *International Journal of Obesity, 35*(7), 937-944. https://doi.org/10.1038/ijo.2011.54

Burton, A., & Miller, D. (1998). *Movement skill assessment*. Human Kinetics.

Butte, N. F., Wong, W. W., Lee, J. S., Adolph, A. L., Puyau, M. R., & Zakeri, I. F. (2014). Prediction of energy expenditure and physical activity in preschoolers. *Med Sci Sports Exerc, 46*(6), 1216-1226. https://doi.org/10.1249/MSS.0000000000000209

Byun, W., Barry, A., & Lee, J. M. (2016). Energy expenditure of daily living activities in 3- to 6-year-old children. *Journal of Physical Activity and Health, 13*(6), S3-S6. https://doi.org/10.1123/jpah.2015-0715

Byun, W., Beets, M. W., & Pate, R. R. (2015). Sedentary behavior in preschoolers: How many days of accelerometer monitoring is needed? *International Journal of Environmental Research & Public Health [Electronic Resource], 12*(10), 13148-13161.

Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoon, L. (2013a). Using accelerometers in youth physical activity studies: A review of methods. *J Phys Act Health, 10*(3), 437-450. https://doi.org/10.1123/jpah.10.3.437

Cain, K. L., Sallis, J. F., Conway, T. L., Van Dyck, D., & Calhoon, L. (2013b). Using accelerometers in youth physical activity studies: A review of methods. *Journal of Physical Activity and Health, 10*(3), 437-450. https://doi.org/10.1123/jpah.10.3.437

Carlson, S. M., White, R. E., & Davis-Unger, A. (2014). Evidence for a relation between executive function and pretense representation in preschool children. *Cogn Dev, 29*. https://doi.org/10.1016/j.cogdev.2013.09.001

Carson, V., Ezeugwu, V. E., Tamana, S. K., Chikuma, J., Lefebvre, D. L., Azad, M. B., Moraes, T. J., Subbarao, P., Becker, A. B., Turvey, S. E., Sears, M. R., & Mandhane, P. J. (2019). Associations between meeting the canadian 24-hour movement guidelines for the early years and behavioral and emotional problems among 3-year-olds. *Journal of Science & Medicine in Sport, 22*(7), 797-802. https://doi.org/10.1016/j.jsams.2019.01.003

Carson, V., Hunter, S., Kuzik, N., Wiebe, S. A., Spence, J. C., Friedman, A., Tremblay, M. S., Slater, L., & Hinkley, T. (2016). Systematic review of physical activity and cognitive development in early childhood. *J Sci Med Sport, 19*(7), 573-578. https://doi.org/10.1016/j.jsams.2015.07.011

Carson, V., Lee, E. Y., Hewitt, L., Jennings, C., Hunter, S., Kuzik, N., Stearns, J. A., Unrau, S. P., Poitras, V. J., Gray, C., Adamo, K. B., Janssen, I., Okely, A. D., Spence, J. C., Timmons, B. W., Sampson, M., & Tremblay, M. S. (2017). Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). *BMC Public Health, 17*, 854. https://doi.org/10.1186/s12889-017-4860-0

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports (1974 -), 100*(2), 126-131.

Chaddock, L., Hillman, C. H., Pontifex, M. B., Johnson, C. R., Raine, L. B., & Kramer, A. F. (2012). Childhood aerobic fitness predicts cognitive performance one year later. *J Sports Sci, 30*(5), 421-430. https://doi.org/10.1080/02640414.2011.647706

Chaput, J. P., Colley, R. C., Aubert, S., Carson, V., Janssen, I., Roberts, K. C., & Tremblay, M. S. (2017a). Proportion of preschool-aged children meeting the canadian 24-hour movement guidelines and associations with adiposity: Results from the canadian health measures survey. *BMC Public Health, 17*, 829.

Chaput, J. P., Gray, C. E., Poitras, V. J., Carson, V., Gruber, R., Birken, C. S., MacLean, J. E., Aubert, S., Sampson, M., & Tremblay, M. S. (2017b). Systematic review of the relationships between sleep duration and health indicators in the early years (0-4 years). *BMC Public Health, 17*, Article 855. https://doi.org/10.1186/s12889-017-4850-2

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Med Sci Sports Exerc, 43*(2), 357-364. https://doi.org/10.1249/MSS.0b013e3181ed61a3

Clark, J. E. (1995). On becoming skillful: Patterns and constraints. *Research Quarterly for Exercersice and Sport, 66*, 173 -183. https://doi.org/02701367.1995.10608831

Cliff, D. P., Reilly, J. J., Okely, A. D., Cliff, D. P., Reilly, J. J., & Okely, A. D. (2009). Methodological considerations in using accelerometers to assess habitual physical activity in children aged 0-5 years. *J Sci Med Sport, 12*(5), 557-567. https://doi.org/10.1016/j.jsams.2008.10.008

Cole, T. J., & Lobstein, T. (2012). Extended international (iotf) body mass index cut-offs for thinness, overweight and obesity. *Pediatr Obes, 7*(4), 284-294. https://doi.org/10.1111/j.2047-6310.2012.00064.x

Colley, R. C., Christidis, T., Michaud, I., Tjepkema, M., & Ross, N. A. (2019). The association between walkable neighbourhoods and physical activity across the lifespan. *Health Reports, 30*(9), 3-13.

Collings, P. J., Brage, S., Ridgway, C. L., Harvey, N. C., Godfrey, K. M., Inskip, H. M., Cooper, C., Wareham, N. J., & Ekelund, U. (2013). Physical activity intensity, sedentary time, and body composition in preschoolers. *American Journal of Clinical Nutrition, 97*(5), 1020-1028.

Cooper, A. R., Goodman, A., Page, A. S., Sherar, L. B., Esliger, D. W., van Sluijs, E. M. F., Andersen, L. B., Anderssen, S., Cardon, G., Davey, R., Froberg, K., Hallal, P., Janz, K. F., Kordas, K., Kreimler, S., Pate, R. R., Puder, J. J., Reilly, J. J., Salmon, J., & Sardinha, L. B. (2015). Objectively measured physical activity and sedentary time in youth: The international children's accelerometry database (icad). *International Journal of Behavioral Nutrition & Physical Activity, 12*, 1-10. https://doi.org/10.1186/s12966-015-0274-5

Coppens, E., Bardid, F., Deconinck, F. J. A., Haerens, L., Stodden, D., D'Hondt, E., & Lenoir, M. (2019). Developmental change in motor competence: A latent growth curve analysis. *Frontiers in Physiology, 10*, 1273. https://doi.org/10.3389/fphys.2019.01273

Corder, K., Sharp, S. J., Atkin, A. J., Griffin, S. J., Jones, A. P., Ekelund, U., & van Sluijs, E. M. (2015). Change in objectively measured physical activity during the transition to adolescence [Research Support, Non-U.S. Gov't]. *British Journal of Sports Medicine, 49*(11), 730-736.

Corder, K., Sluijs, E. M. F. v., Ekelund, U., Jones, A. P., & Griffin, S. J. (2010). Changes in children's physical activity over 12 months: Longitudinal results from the speedy study. *Pediatrics, 126*(4), e926-e935. https://doi.org/10.1542/peds.2010-0048

Cortes-Patino, D. M., Soares-Filho, P. S. D., & Acosta-Barreto, M. R. (2017). Decision-making in children in the hungry donkey test: A behavioral analysis. *Dev Neuropsychol, 42*(7-8), 521-533. https://doi.org/10.1080/87565641.2017.1404065

Costa, S., Barber, S. E., Cameron, N., & Clemes, S. A. (2014). Calibration and validation of the actigraph gt3x+ in 2-3 year olds [Clinical Trial
Comparative Study
Research Support, Non-U.S. Gov't]. *J Sci Med Sport, 17*(6), 617-622.

Coumans, J. M. J., Danner, U. N., Ahrens, W., Hebestreit, A., Intemann, T., Kourides, Y. A., Lissner, L., Michels, N., Moreno, L. A., Russo, P., Stomfai, S., Veidebaum, T., & Adan, R. A. H. (2018). The association of emotion-driven impulsiveness, cognitive inflexibility and decision-making with weight status in european adolescents. *Int J Obes (Lond), 42*(4), 655-661. https://doi.org/10.1038/ijo.2017.270

Coyle-Asbil, H. J., Breau, B., Ma, D. W. L., Haines, J., Vallis, L. A., & Guelph Family Health Study. (2020). Examining the effects of applying actigraph low-frequency extension feature to analyze the sleeping behaviours of preschool-aged children. *Appl Physiol Nutr Metab, 45*(12), 1396-1399. https://doi.org/10.1139/apnm-2019-0969

Craig, W., Pickett, W., & King, M. (2020). The heatlh of canadian youth: Findings from the health behaviour in school-sged children study. *Public Health Agency of Canada*.

Crone, E. A., & van der Molen, M. W. (2004). Developmental changes in real life decision making: Performanc on a gambling task previously shown to depend on the ventromedial prefrontal cortex. *Developmental Neuropsychology, 25*(3), 251-279.

De Bock, F., Menze, J., Becker, S., Litaker, D., Fischer, J., & Seidel, I. (2010). Combining accelerometry and hr for assessing preschoolers' physical activity [Research Support, Non-U.S. Gov't
Research Support, U.S. Gov't, Non-P.H.S.]. *Medicine & Science in Sports & Exercise, 42*(12), 2237-2243.

De Henauw, S., Huybrechts, I., De Bourdeaudhuij, I., Bammann, K., Barba, G., Lissner, L., Marild, S., Molnar, D., Moreno, L. A., Pigeot, I., Tornaritis, M., Veidebaum, T., Verbestel, V., Ahrens, W., & consortium, I. (2015). Effects of a community-oriented obesity prevention programme on indicators of body fatness in preschool and primary school children. Main results from the idefics study. *Obes Rev, 16 Suppl 2*, 16-29. https://doi.org/10.1111/obr.12346

De Miguel-Etayo, P., Gracia-Marco, L., Ortega, F. B., Intemann, T., Foraita, R., Lissner, L., Oja, L., Barba, G., Michels, N., Tornaritis, M., Molnar, D., Pitsiladis, Y., Ahrens, W., Moreno, L. A., & consortium, I. (2014). Physical fitness reference standards in european children: The idefics study. *Int J Obes (Lond), 38 Suppl 2*, S57-66. https://doi.org/10.1038/ijo.2014.136

De Vries, S. I., Van Hirtum, H. W., Bakker, I., Hopman-Rock, M., Hirasing, R. A., & Van Mechelen, W. (2009). Validity and reproducibility of motion sensors in youth: A systematic update. *Med Sci Sports Exerc, 41*(4), 818-827. https://doi.org/10.1249/MSS.0b013e31818e5819

Donnelly, J. E., Hillman, C. H., Castelli, D., Etnier, J. L., Lee, S., Tomporowski, P., Lambourne, K., & Szabo-Reed, A. N. (2016). Physical activity, fitness, cognitive function, and academic achievement in children: A systematic review. *Med Sci Sports Exerc, 48*(6), 1197-1222. https://doi.org/10.1249/MSS.0000000000000901

Dosman, C. F., Andrews, D., & Goulden, K. J. (2012). Evidence-based milestone ages as a framework for developmental surveillance. *Pediatr Child Health, 17*(10), 561-568.

Dumith, S. C., Gigante, D. P., Domingues, M. R., & Kohl, H. W., 3rd. (2011). Physical activity change during adolescence: A systematic review and a pooled analysis. *Int J Epidemiol, 40*(3), 685-698. https://doi.org/10.1093/ije/dyq272

Ekelund, U. L., J. Sherar, L. B. Esliger, D. W. Griew, P. Cooper, A. Ekelund, Ulf Luan, Jian'an Sherar, Lauren B. Esliger, Dale W. Griew, Pippa Cooper, Ashley. (2012). Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA: Journal of the American Medical Association, 307*(7), 704-712.

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *J Sports Sci, 26*(14), 1557-1565. https://doi.org/10.1080/02640410802334196

Fang, H., Quan, M., Zhou, T., Sun, S., Zhang, J., Zhang, H., Cao, Z., Zhao, G., Wang, R., & Chen, P. (2017). Relationship between physical activity and physical fitness in preschool children: A cross-sectional study. *BioMed Research International, 2017*, 1-8. https://doi.org/10.1155/2017/9314026

Fang, Z., Langford, J., & Sweetland, C. (2019). *Genearead: Package for reading binary files.* In https://CRAN.R-project.org/package=GENEAread

Farooq, M. A., Parkinson, K. N., Adamson, A. J., Pearce, M. S., Reilly, J. K., Hughes, A. R., Janssen, X., Basterfield, L., & Reilly, J. J. (2018). Timing of the decline in physical activity in childhood and adolescence: Gateshead millennium cohort study. *Br J Sports Med, 52*(15), 1002-1006. https://doi.org/10.1136/bjsports-2016-096933

Figueroa, R., & An, R. (2017). Motor skill competence and physical activity in preschoolers: A review. *Maternal and child health journal, 21*(1), 136-146. https://doi.org/10.1007//s10995-016-2102-1

Freedson, P., Pober, D., & Janz, K. F. (2005). Calibration of accelerometer output for children. *Med Sci Sports Exerc, 37*(11 Suppl), S523-530. https://doi.org/10.1249/01.mss.0000185658.28284.ba

Gallahue, D. L., & Ozmun, J. C. (2000). *Understanding motor development: Infants, children, adolescents, adults*. McGraw-Hill College.

Guan, H., Zhang, Z., Wang, B., Okely, A. D., Tong, M., Wu, J., & Zhang, T. (2020). Proportion of kindergarten children meeting the who guidelines on physical activity, sedentary behaviour and sleep and associations with adiposity in urban beijing. *BMC Pediatrics, 20*(1), 1-9.

Gutierrez-Hervas, A., Cortes-Castell, E., Juste-Ruiz, M., & Rizo-Baeza, M. (2020). Which variables influence compliance with physical activity recommendations in young children? *Anales De Pediatria, 92*(3), 156-164.

Haas, P., Yang, C. H., & Dunton, G. F. (2021). Associations between physical activity enjoyment and age-related decline in physical activity in children-results from a longitudinal within-person study. *J Sport Exerc Psychol*, 1-10. https://doi.org/10.1123/jsep.2020-0156

Heaton, R. K., Chelune, G. J., Talley, J. L., Kay, G. G., & Curtiss, G. (1993). *Wisconsin card sorting test manual: Revised and expanded*. Psychological Assessment Resources.

Hislop, J., Palmer, N., Anand, P., & Aldin, T. (2016). Validity of wrist worn accelerometers and comparability between hip and wrist placement sites in estimating physical activity behaviour in preschool children. *Physiol Meas, 37*(10), 1701-1714. https://doi.org/10.1088/0967-3334/37/10/1701

Hislop, J. F., Bulley, C., Mercer, T. H., & Reilly, J. J. (2012). Comparison of accelerometry cut points for physical activity and sedentary behavior in preschool children: A validation study. *Pediatric Exercise Science, 24*(4), 563-576. https://doi.org/10.1123/pes.24.4.563

Holfelder, B., & Schott, N. (2014). Relationship of fundamental movement skills and physical activity in children and adolescents: A systematic review. *Psychology of Sport and Exercise, 15*(4), 382-391. https://doi.org/10.1016/j.psychsport.2014.03.005

Huotari, P., Nupponen, H., Mikkelsson, L., Laakso, L., & Kujala, U. (2011). Adolescent physical fitness and activity as predictors of adulthood activity. *J Sports Sci, 29*(11), 1135-1141. https://doi.org/10.1080/02640414.2011.585166

Iivonen, K. S., Saakslahti, A. K., Mehtala, A., Villberg, J. J., Tammelin, T. H., Kulmala, J. S., & Poskiparta, M. (2013). Relationship between fundamental motor skills and physical activity in 4-year-old preschool children. *Percept Mot Skills, 117*(2), 627-646. https://doi.org/10.2466/10.06.PMS.117x22z7

Inchley, J., Currie, D., Budisavljevic, S., Torsheim, T., Jåstad, A., Cosma, A., & et al., e. (2020). *Spotlight on adolescent health and well-being. Findings from the 2017/2018 health behaviours in school-aged children (hbsc) survery in europe and canada. International report. Volume 1. Key findings*. WHO Regional Office for Europe.

Jaakkola, T., Kalaja, S., Liukkonen, J., Jultila, A., & Virtanen, P. (2009). Relations among physical activity patterns, lifestyls activities, and fundamental movment skills for finnish students in grade 7. *Percept Mot Skills, 108*(1), 97-111. https://doi.org/http://dx.doi.org/10.2466/pms.108.1.97-111

Jaakkola, T., Yli-Piipari, S., Huhtiniemi, M., Salin, K., Seppälä, S., Hakonen, H., & Gråstén, A. (2019). Longitudinal associations among cardiorespiratory and muscular fitness, motor competence and objectively measured physical activity. *Journal of Science & Medicine in Sport, 22*(11), 1243-1248. https://doi.org/10.1016/j.jsams.2019.06.018

Jaakkola, T., Yli-Piipari, S., Huotari, P., Watt, A., & Liukkonen, J. (2016). Fundamental movement skills and physical fitness as predictors of physical activity: A 6-year follow-up study. *Scand J Med Sci Sports, 26*(1), 74-81. https://doi.org/10.1111/sms.12407

Janssen, X., Cliff, D. P., Reilly, J. J., Hinkley, T., Jones, R. A., Batterham, M., Ekelund, U., Brage, S., & Okely, A. D. (2013). Predictive validity and classification accuracy of actigraph energy expenditure equations and cut-points in young children. *PLoS ONE [Electronic Resource], 8*(11), e79124. https://doi.org/10.1371/journal.pone.0079124

Jimmy, G., Seller, R., & Maeder, U. (2013). Development and validation of energy expenditure prediction models based on gt3x accelerometer data in 5- to 9-year-old children. *J Phys Act Health, 10*, 1057-1067.

Jones, D., Innerd, A., Giles, E. L., & Azevedo, L. B. (2020). Association between fundamental motor skills and physical activity in the early years: A systematic review and meta-analysis. *Journal of Sport and Health Science*. https://doi.org/10.1016/j.jshs.2020.03.001

Jones, R. A., Hinkley, T., Okely, A. D., & Salmon, J. (2013). Tracking physical activity and sedentary behavior in childhood: A systematic review. *Am J Prev Med, 44*(6), 651-658. https://doi.org/10.1016/j.amepre.2013.03.001

Kahan, D., Nicaise, V., & Reuben, K. (2013). Convergent validity of four accelerometer cutpoints with direct observation of preschool children's outdoor physical activity. *Research Quarterly for Exercise & Sport, 84*(1), 59-67. https://doi.org/10.1080/02701367.2013.762294

Kambas, A., Michalopoulou, M., Fatouros, I. G., Christoforidis, C., Manthou, E., & Giannakidou, D. (2012). The relationship between motor proficiency and pedometer-determined physical activity in young children. *Pediatric Exercise Science, 24*, 34-44.

Katzmarzyk, P. T., Barreira, T. V., Broyles, S. T., Champagne, C. M., Chaput, J.-P., Fogelholm, M., Hu, G., Johnson, W. D., Kuriyan, R., Kurpad, A., Lambert, E. V., Maher, C., Maia, J., Matsudo, V., Olds, T., Onywera, V., Sarmiento, O. L., St, age, M., Tremblay, M. S., & Tudor-Locke, C. (2013). The international study of childhood obesity, lifestyle and the environment (iscole): Design and methods. *BMC Public Health, 13*(1), 900-900.

Klein, D. (2011). *Bewegungs-und gesundheitsförderung in kindergärten - wirkungsanalyse ausgewählter kölner interventionen*

Klein, D., Koch, B., Dordel, S., Strüder, H., & Graf, C. (2012). The kimo test: A motor screening for pre-school children aged 3-6 years. *Gazzetta Medica Italiana, 171*(1), 13-26.

Konstabel, K., Veidebaum, T., Verbestel, V., Moreno, L. A., Bamman, K., Tornaritis, M., Eiben, G., Molnár, D., Siani, A., Sprengeler, O., Wirsik, N., Ahrens, W., Pitsiladis, Y., & consortium, o. b. o. t. I. (2014). Objectively measured physical activity in european children: The idefics study. *International Journal of Obesity, 38*, S135-S143. https://doi.org/10.1038/ijo.2014.144

Koslow, R. E. (1987). Sit and reach flexibility measures for boys and girls aged three through eight years. *Perceptual & Motor Skills, 64*, 1103-1106. https://doi.org/https://doi.org/10.2466%2Fpms.1987.64.3c.1103

Krombholz, H. (2006). Physical performance in relation to age, sex, birth order, social class, and sports activities of preschool children. *Percept Mot Skills, 102*(2), 477-484.

Kuzik, N., Poitras, V. J., Tremblay, M. S., Lee, E. Y., Hunter, S., & Carson, V. (2017). Systematic review of the relationships between combinations of movement behaviours and health indicators in the early years (0-4 years). *BMC Public Health, 17*(Suppl 5), 849. https://doi.org/10.1186/s12889-017-4851-1

Lee, E. Y., Hesketh, K. D., Hunter, S., Kuzik, N., Rhodes, R. E., Rinaldi, C. M., Spence, J. C., & Carson, V. (2017). Meeting new canadian 24-hour movement guidelines for the early years and associations with adiposity among toddlers living in edmonton, canada. *BMC Public Health, 17*, 840.

Leeger-Aschmann, C. S. S., E. A., Zysset, A. E., Kakebeeke, T. H., Messerli-Burgy, N., Stulb, K., Arhab, A., Meyer, A. H., Munsch, S., Jenni, O. G., Puder, J. J., & Kriemler, S. (2019). Accelerometer-derived physical activity estimation in preschoolers - comparison of cut-point sets incorporating the vector magnitude vs the vertical axis. *BMC Public Health, 19*(1), 513.

Lees, C., & Hopkins, J. (2013). Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: A systematic review of randomized control trials. *Prev Chronic Dis, 10*, E174. https://doi.org/10.5888/pcd10.130010

Leger, L. A., Mercier, D., Gadoury, C., & Lambert, J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci, 6*(2), 93-101. https://doi.org/10.1080/02640418808729800

Leppanen, M. H., Henriksson, P., Henriksson, H., Delisle Nystrom, C., Llorente-Cantarero, F. J., & Lof, M. (2018). Physical activity level using doubly-labeled water in relation to body composition and physical fitness in preschoolers. *Medicina (Kaunas), 55*(1). https://doi.org/10.3390/medicina55010002

Leppanen, M. H., Kaseva, K., Pajulahti, R., Saaksjarvi, K., Makynen, E., Engberg, E., Ray, C., Erkkola, M., Sajaniemi, N., & Roos, E. (2021). Temperament, physical activity and sedentary time in preschoolers - the dagis study. *BMC Pediatrics, 21*(1), 129.

Loprinzi, P. D., & Frith, E. (2017). Motor skills and free-living physical activity showed no association among preschoolers in 2012 u.S. National youth fitness survey. *Percept Mot Skills, 124*(2), 321-328. https://doi.org/10.1177/0031512516684458

Määttä, S., Konttinen, H., de Oliveira Figueiredo, R. A., Haukkala, A., Sajaniemi, N., Erkkola, M., & Roos, E. (2020). Individual-, home- and preschool-level correlates of preschool children's sedentary time. *BMC Pediatrics, 20*(1), 1-14.

McNeill, J., Howard, S. J., Vella, S. A., Santos, R., & Cliff, D. P. (2018). Physical activity and modified organized sport among preschool children: Associations with cognitive and psychosocial health. *Mental Health and Physical Activity, 15*, 45-52. https://doi.org/10.1016/j.mhpa.2018.07.001

Migueles, J. H., Cadenas-Sanchez, C., Ekelund, U., Delisle Nystrom, C., Mora-Gonzalez, J., Lof, M., Labayen, I., Ruiz, J. R., & Ortega, F. B. (2017). Accelerometer data collection and processing criteria to assess physical activity and other outcomes: A systematic review and practical considerations. *Sports Med, 47*(9), 1821-1845. https://doi.org/10.1007/s40279-017-0716-0

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cogn Psychol, 41*(1), 49-100. https://doi.org/10.1006/cogp.1999.0734

Mueller, S. T., & Piper, B. J. (2014). The psychology experiment building language (pebl) and pebl test battery. *J Neurosci Methods, 222*, 250-259. https://doi.org/10.1016/j.jneumeth.2013.10.024

Myatt, M., & Guevarra, E. (2019). *Zscorer: Child antrhopometry z-score calculator.* In (Version version 0.3.1.) R package https://CRAN.R-project.org/package=zscorer

NCBI. (n.d.). *Physical fitness*. National Center for Biotechnology Information Retrieved February 14th 2021 from https://www.ncbi.nlm.nih.gov/mesh/68010809

Nettlefold, L., Naylor, P. J., Warburton, D. E., Bredin, S. S., Race, D., & McKay, H. A. (2016). The influence of epoch length on physical activity patterns varies by child's activity level [Research Support, Non-U.S. Gov't]. *Research Quarterly for Exercise & Sport, 87*(1), 110-123.

NHANES. (2011). Physical activity monitor (pam) procedures manual. 1-36.

Nicolai Ré, A. H., Okely, A. D., Logan, S. W., da Silva, M. M. L. M., Cattuzzo, M. T., & Stodden, D. F. (2020). Relationship between meeting physical activity guidelines and motor competence among low-income school youth. *Journal of Science & Medicine in Sport, 23*(6), 591-595.

Niederer, I., Kriemler, S., Gut, J., Hartmann, T., Schindler, C., Barral, J., & Puder, J. J. (2011). Relationship of aerobic fitness and motor skils with memory and attention in preschoolers (ballabeina): A cross-sectional and longitudinal study. *BMC Pediatrics, 11*(1), 34.

Nilsen, A. K. O., Anderssen, S. A., Loftesnes, J. M., Johannessen, K., Ylvisaaker, E., & Aadland, E. (2020). The multivariate physical activity signature associated with fundamental motor skills in preschoolers. *Journal of Sports Sciences, 38*(3), 264-272.

Okely, A. D., Lubans, D. R., Morgan, P. J., Cotton, W., Peralta, L., Miller, J., Batterham, M., & Janssen, X. (2017). Promoting physical activity among adolescent girls: The girls in sport group randomized trial. *International Journal of Behavioral Nutrition and Physical Activity, 14*(81), (21 June 2017). https://doi.org/10.1186/s12966-017-0535-6

Olesen, L. G. K., P. L. Ried-Larsen, M. Grontved, A. Froberg, K. (2014). Physical activity and motor skills in children attending 43 preschools: A cross-sectional study. *BMC Pediatrics, 14*, 229. https://doi.org/https://doi.org/10.1186/1471-2431-14-229

Oliver, M., Schofield, G. M., & Kolt, G. S. (2007). Physical activity in preschoolers: Understanding prevalence and measurement issues. *Sports Med, 37*(12), 1045-1070.

Ortega, F. B., Ruiz, J. R., Castillo, M. J., & Sjostrom, M. (2008). Physical fitness in childhood and adolescence: A powerful marker of health. *Int J Obes (Lond), 32*(1), 1-11. https://doi.org/10.1038/sj.ijo.0803774

Pate, R. R., Almeida, M. J., McIver, K. L., Pfeiffer, K. A., & Dowda, M. (2006). Validation and calibration of an accelerometer in preschool children. *Obesity (Silver Spring), 14*(11), 2000-2006. https://doi.org/10.1038/oby.2006.234

Pate, R. R., O'Neill, J. R., Brown, W. H., Pfeiffer, K. A., Dowda, M., & Addy, C. L. (2015). Prevalence of compliance with a new physical activity guideline for preschool-age children. *Childhood Obesity, 11*(4), 415-420. https://doi.org/10.1089/chi.2014.0143

Pate, R. R., O'Neill, J. R., & Mitchell, J. (2010). Measurement of physical activity in preschool children. *Medicine & Science in Sports & Exercise, 42*(3), 508-512.

Penpraze, V., Reilly, J., Maclean, C. M., Montgomery, C., Kelly, L., Paton, J. Y., Aitchison, T., & Grant, S. (2006). Monitoring of physical activity in young children: How much is enough? *Pediatr Exerc Sci, 18*(4), 483-491. https://doi.org/http://dx.doi.org/10.1123/pes.18.4.483

Pfeiffer, K. A., Dowda, M., McIver, K. L., & Pate, R. R. (2009). Factors related to objectively measured physical activity in preschool children. *Pediatr Exerc Sci, 21*(2), 196-208.

Pfeiffer, K. A., McIver, K. L., Dowda, M., Almeida, M. J., & Pate, R. R. (2006). Validation and calibration of the actical accelerometer in preschool children. *Med Sci Sports Exerc, 38*(1), 152-157. https://doi.org/10.1249/01.mss.0000183219.44127.e7

Phillips, L. R., Parfitt, G., & Rowlands, A. V. (2013). Calibration of the genea accelerometer for assessment of physical activity intensity in children. *J Sci Med Sport, 16*(2), 124-128. https://doi.org/10.1016/j.jsams.2012.05.013

Poitras, V. J., Gray, C. E., Borghese, M. M., Carson, V., Chaput, J. P., Janssen, I., Katzmarzyk, P. T., Pate, R. R., Connor Gorber, S., Kho, M. E., Sampson, M., & Tremblay, M. S. (2016). Systematic review of the relationships between objectively measured physical activity and health indicators in school-aged children and youth. *Appl Physiol Nutr Metab, 41*(6 Suppl 3), S197-239. https://doi.org/10.1139/apnm-2015-0663

Poitras, V. J., Gray, C. E., Janssen, X., Aubert, S., Carson, V., Faulkner, G., Goldfield, G. S., Reilly, J. J., Sampson, M., & Tremblay, M. S. (2017). Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0-4 years). *BMC Public Health, 17*(Suppl 5), 868. https://doi.org/10.1186/s12889-017-4849-8

Potter, M., Spence, J. C., Boule, N., Stearns, J. A., & Carson, V. (2018). Behavior tracking and 3-year longitudinal associations between physical activity, screen time, and fitness among young children. *Pediatr Exerc Sci, 30*(1), 132-141. https://doi.org/10.1123/pes.2016-0239

Pulsford, R. M., Cortina-Borja, M., Rich, C., Kinnafick, F.-E., Dezateux, C., & Griffiths, L. J. (2011). Actigraph accelerometer-defined boundaries for sedentary behaviour and physical activity intensities in 7 year old children. *PLoS One, 6*(8), e21822.

Puyau, M., Adolph, A. L., Firoz, A. V., & Butte, N. F. (2002). Validation and calibration of physical activity monitors in children. *Obesity Research, 10*, 150-157.

R Core Team. (2017). *R: A language and environment for statistical computing.* In R Foundation for Statistical Computing. https://www.R-project.org/.

Reilly, J. J. (2010). Low levels of objectively measured physical activity in preschoolers in child care. *Med Sci Sports Exerc, 42*(3), 502-507. https://doi.org/10.1249/MSS.0b013e3181cea100

Ricardo, L. I. C., da Silva, I. C. M., Leao, O. A. D., Domingues, M. R., & Wehrmeister, F. C. (2019). Objectively measured physical activity in one-year-old children from a brazilian cohort: Levels, patterns and determinants. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1).

Roberts, K. C., Yao, X., Carson, V., Chaput, J. P., Janssen, I., & Tremblay, M. S. (2017). Meeting the canadian 24-hour movement guidelines for children and youth. *Health Rep, 28*(10), 3-7.

Robinson, L. E., Stodden, D. F., Barnett, L. M., Lopes, V. P., Logan, S. W., Rodrigues, L. P., & D'Hondt, E. (2015). Motor competence and its effect on positive developmental trajectories of health. *Sports Medicine, 45*(9), 1273-1284. https://doi.org/10.1007/s40279-015-0351-6

Roscoe, C. M. P., James, R. S., & Duncan, M. J. (2017). Calibration of geneactiv accelerometer wrist cut-points for the assessment of physical activity intensity of preschool aged children. *Eur J Pediatr, 176*(8), 1093-1098. https://doi.org/10.1007/s00431-017-2948-2

Rowlands, A. V., Rennie, K., Kozarski, R., Stanley, R. M., Eston, R. G., Parfitt, G. C., & Olds, T. S. (2014). Children's physical activity assessed with wrist- and hip-worn accelerometers [Validation Studies]. *Medicine & Science in Sports & Exercise, 46*(12), 2308-2316.

Ruiz, J. R., España Romero, V., Castro Piñero, J., Artero, E. G., Ortega, F. B., Cuenca García, M., Jiménez Pavón, D., Chillón, P., Girela Rejón, M. J., Mora, J., Gutiérrez, A., Suni, J., Sjöstrom, M., & Castillo, M. J. (2011). Alpha-fitness test battery: Health-related field-based fitness tests assessment in children and adolescents. *Nutrición hospitalaria : organo oficial de la Sociedad Española de Nutrición Parenteral y Enteral, 26*(6), 1210.

Ruiz, J. R., Espana-Romero, V., Ortega, F. B., Sjostrom, M., Castillo, M. J., & Gutierrez, A. (2006). Hand span influences optimal grip span in male and female teenagers. *J Hand Surg Am, 31*(8), 1367-1372. https://doi.org/10.1016/j.jhsa.2006.06.014

Rullestad, A., Meland, E., & Mildestvedt, T. (2021). Factors predicting physical activity and sports participation in adolescence. *J Environ Public Health, 2021*, 9105953. https://doi.org/10.1155/2021/9105953

Sabia, S., van Hees, V. T., Shipley, M. J., Trenell, M. I., Hagger-Johnson, G., Elbaz, A., Kivimaki, M., & Singh-Manoux, A. (2014). Association between questionnaire- and accelerometer-assessed physical activity: The role of sociodemographic factors. *American Journal of Epidemiology, 179*(6), 781-790. https://doi.org/10.1093/aje/kwt330

Sadeh, A., Sharkey, M., & Carskadon, M. A. (1994). Activity-based sleep-wake identification: An empirical test of methodological issued. *Sleep, 17*(3), 201-207. https://doi.org/0.1093/sleep/17.3.201

Sallis, J. F., & Saelens, B. E. (2007). Assessment of physical activity by self-report: Status, limitations and future directions. *Research quarterly for exercise and sport, 71*(2), 1 - 14.

Sarker, H. A., L. N. Borkhoff, C. M. Abreo, K. Tremblay, M. S. Lebovic, G. Maguire, J. L. Parkin, P. C. Birken, C. S. Collaboration, T. ARGet Kids. (2015). Validation of parent-reported physical activity and sedentary time by accelerometry in young children. *BMC Research Notes, 8*, 735.

Sasaki, J. E., John, D., & Freedson, P. S. (2011). Validation and comparison of actigraph activity monitors. *J Sci Med Sport, 14*(5), 411-416. https://doi.org/10.1016/j.jsams.2011.04.003

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activty and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*, 243-256.

Sirard, J. R., & Pate, R. R. (2001). Physical activity assessment in children and adolescents. *Sports Med, 31*(6), 439-454.

Sirard, J. R., Trost, S. G., Pfeffer, K. A., Dowda, M., & Pate, R. R. (2005). Calibration and evaluation of an objective measure of physical activity in preschool children. *J Phys Act Health, 3*, 345-357.

Small, L. B.-M., Darya Gannon, Alex M. (2013). Physical activity of young overweight and obese children: Parent reports of child activity level compared with objective measures. *Western Journal of Nursing Research, 35*(5), 638-654.

Spear, L. P. (2000). The adolescent brain and age-related behavioral manifestations. *Neuroscience and Biobehavioral Reviews, 24*, 417-463.

Steenbock, B., Wright, M. N., Wirsik, N., & Brandes, M. (2019). Accelerometry-based prediction of energy expenditure in preschoolers. *Journal for the Measurement of Physical Behaviour, 2*(2), 94-102. https://doi.org/10.1123/jmpb.2018-0032

Steenbock, B., Zeeb, H., Rach, S., Pohlabeln, H., & Pischke, C. R. (2017). Design and methods for a cluster-controlled trial conducted at sixty-eight daycare facilities evaluating the impact of jolinchenkids - fit and healthy in daycare, a program for health promotion in 3- to 6-year-old children. *BMC Public Health, 18*(1), 6. https://doi.org/10.1186/s12889-017-4551-x

Stodden, D. F., Gao, Z., Goodway, J. D., & Langendorfer, S. J. (2014). Dynamic relationships between motor skill competence and health-related fitness in youth. *Pediatric Exercise Science, 26*(3), 231-241. https://doi.org/10.1123/pes.2013-0027

Stodden, D. F., Goodway, J. D., Langendorfer, S. J., Roberton, M. A., Rudisill, M. E., Garcia, C., & Garcia, L. E. (2008). A developmental perspective on the role of motor skill competence in physical activity: An emergent relationship. *Quest, 60*(2), 290-306. https://doi.org/10.1080/00336297.2008.10483582

Stookey, A. D., Mealey, L. M., & Shaughnessy, M. (2011). Physical activity assessment in children. *Journal of Exercise Physiology, 14*(5), 75.

Timmons, B. W., Leblanc, A. G., Carson, V., Connor Gorber, S., Dillman, C., Janssen, I., Kho, M. E., Spence, J. C., Stearns, J. A., & Tremblay, M. S. (2012). Systematic review of physical activity and health in the early years (aged 0-4 years). *Appl Physiol Nutr Metab, 37*(4), 773-792. https://doi.org/10.1139/h2012-070

Tremblay, M. S., Carson, V., Chaput, J. P., Connor Gorber, S., Dinh, T., Duggan, M., Faulkner, G., Gray, C. E., Gruber, R., Janson, K., Janssen, I., Katzmarzyk, P. T., Kho, M. E., Latimer-Cheung, A. E., LeBlanc, C., Okely, A. D., Olds, T., Pate, R. R., Phillips, A., Poitras, V. J., Rodenburg, S., Sampson, M., Saunders, T. J., Stone, J. A., Stratton, G., Weiss, S. K., & Zehr, L. (2016). Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab, 41*(6 Suppl 3), S311-327. https://doi.org/10.1139/apnm-2016-0151

Tremblay, M. S., Chaput, J. P., Adamo, K. B., Aubert, S., Barnes, J. D., Choquette, L., Duggan, M., Faulkner, G., Goldfield, G. S., Gray, C. E., Gruber, R., Janson, K., Janssen, I., Janssen, X., Jaramillo Garcia, A., Kuzik, N., LeBlanc, C., MacLean, J., Okely, A. D., Poitras, V. J., Rayner, M. E., Reilly, J. J., Sampson, M., Spence, J. C., Timmons, B. W., & Carson, V. (2017). Canadian 24-hour movement guidelines for the early years (0-4 years): An integration of physical activity, sedentary behaviour, and sleep. *BMC Public Health, 17*(Suppl 5), 874. https://doi.org/10.1186/s12889-017-4859-6

Trost, S. G., Fees, B. S., Haar, S. J., Murray, A. D., & Crowe, L. K. (2012). Identification and validity of accelerometer cut-points for toddlers. *Obesity (Silver Spring), 20*(11), 2317-2319. https://doi.org/10.1038/oby.2011.364

Tudor-Locke, C., Barreira, T. V., Schuna, J. M., Mire, E. F., Chaput, J. P., Fogelholm, M., Hu, G., Kuriyan, R., Kurpad, A., Lambert, E. V., Maher, C., Maia, J., Matsudo, V., Olds, T., Onywera, V., Sarmiento, O. L., Standage, M., Tremblay, M. S., Zhao, P., Church, T. S., Katzmarzyk, P. T., & Grp, I. R. (2015). Improving wear time compliance with a 24-hour waist-worn accelerometer protocol in the international study of childhood obesity, lifestyle and the environment (iscole). *International Journal of Behavioral Nutrition and Physical Activity, 12*, Article 11. https://doi.org/10.1186/s12966-015-0172-x

Tudor-Locke, C., Barreira, T. V., Schuna, J. M., Mire, E. F., & Katzmarzyk, P. T. (2014). Fully automted waist-worn acceleroemter algorithm for detecting children's sleep-period time separate form 24-h physical activity or sedentary behaviours. *Appl Physiol Nutr Metab, 39*(1), 53-57. https://doi.org/apnm-2019-0969apnm- 2013-0173

UNESCO. (2012). *International standard classificaiton of education 2011*. UNESCO Institute for Statistics. http://uis.unesco.org/sites/default/files/documents/international-standard-classification-of-education-isced-2011-en.pdf

Utesch, T., Bardid, F., Busch, D., & Strauss, B. (2019a). The relationship between motor competence and physical fitness from early childhood to early adulthood: A meta-analysis. *Sports Medicine, 49*(4), 541-551. https://doi.org/10.1007/s40279-019-01068-y

Utesch, T., Bardid, F., Büsch, D., & Strauss, B. (2019b). Motor competence. In *Dictionary of Sport Psychology: Sport, Exercise, and Performaing Arts*.

Vale, S., Santos, R., Silva, P., Soares-Miranda, L., & Mota, J. (2009). Preschool children physical activity measurement: Importance of epoch length choice. *Pediatric Exercise Science, 21*(4), 413-420. https://doi.org/10.1123/pes.21.4.413

van Cauwenberghe, E. L., V. Trost, S. G. de Bourdeaudhuij, I. Cardon, G. (2011). Calibration and comparison of accelerometer cut points in preschool children. *Int J Pediatr Obes, 6*(2), e582-589. https://doi.org/10.3109/17477166.2010.526223

van Hees, V. T., Gorzelniak, L., Dean Leon, E. C., Eder, M., Pias, M., Taherian, S., Ekelund, U., Renstrom, F., Franks, P. W., Horsch, A., & Brage, S. (2013). Separating movement and gravity components in an acceleration signal and implications for the assessment of human daily physical activity. *PLoS One, 8*(4), e61691. https://doi.org/10.1371/journal.pone.0061691

Vandorpe, B., Vandendriessche, J., Vaeyens, R., Pion, J., Matthys, S., Lefevre, J., Philippaerts, R., & Lenoir, M. (2012). Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach. *Journal of Science & Medicine in Sport, 15*(3), 220-225. https://doi.org/10.1016/j.jsams.2011.09.006

Venetsanou, F., & Kambas, A. (2017). Can motor proficiency in preschool age affect physical activity in adolescence? *Pediatric Exercise Science, 29*(2), 254-259. https://doi.org/10.1123/pes.2016-0119

Webster, E. K., Martin, C. K., & Staiano, A. E. (2019). Fundamental motor skills, screen-time, and physical activity in preschoolers. *Journal of Sport and Health Science, 8*(2), 114-121. https://doi.org/10.1016/j.jshs.2018.11.006

Wijndaele, K., Westgate, K., Stephens, S. K., Blair, S. N., Bull, F. C., Chastin, S. F., Dunstan, D. W., Ekelund, U., Esliger, D. W., Freedson, P. S., Granat, M. H., Matthews, C. E., Owen, N., Rowlands, A. V., Sherar, L. B., Tremblay, M. S., Troiano, R. P., Brage, S., & Healy, G. N. (2015). Utilization and harmonization of adult accelerometry data: Review and expert consensus. *Med Sci Sports Exerc, 47*(10), 2129-2139. https://doi.org/10.1249/MSS.0000000000000661

Williams, H. G., Pfeiffer, K. A., O'Neill, J. R., Dowda, M., McIver, K. L., Brown, W. H., & Pate, R. R. (2008). Motor skill performance and physical activity in preschool children. *Obesity (Silver Spring), 16*(6), 1421-1426. https://doi.org/10.1038/oby.2008.214

World Health Organization. (2010a). *Antiretroviral therapy for hiv infection in infants and children: Towards universal access: Recommendations for a public health approach" 2010 revision.* Retrieved June 17th 2021 from https://www.ncbi.nlm.nih.gov/books/NBK138588/

World Health Organization. (2010b). Global recommendations on physical activity for health.

World Health Organization. (2019). Guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age.

World Health Organization. (2020). Noncommunicable diseases: Childhood overweight and obesity.

Wrotniak, B. H., Epstein, L. H., Dorn, J. M., Jones, K. E., & Kondilis, V. A. (2006). The relationship between motor proficiency and physical activity in children. *Pediatrics, 118*(6), e1758-1765. https://doi.org/10.1542/peds.2006-0742

APPENDICES – CHAPTER 2 SEARCH STRATEGIES

Round 1 Searches – August 16th, 2019

Table A.1: Initial Search Strategy conducted in Medline (via OvidSP)

#	Search Terms	Results
1	(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivPal or activity monitor* or wearable device* or tracker*).ab,kf,ti.	47949
2	exp Accelerometry/	7500
3	exp Fitness Trackers/	305
4	(child* or infant* or preschool* or pre-school* or toddler* or kid*).ab,kf,ti	2047176
5	exp Child, Preschool/	884538
6	exp Infant/	1101959
7	(physical activity or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or physical inactivity or screen time).ab,kf,ti.	896846
8	exp Exercise/	180825
9	exp Sedentary Lifestyle/	8041
10	exp Pediatric Obesity/	6929
11	1 or 2 or 3	49653
12	4 or 5 or 6	2735618
13	7 or 8 or 9 or 10	968209
14	11 and 12 and 13	3186
15	14 and 2009:2019	2763
	FINAL SEARCH AUGUST 16TH	**2793**

Table A.2: Initial Search Strategy conducted in CINAHL

#	Search Terms	Results
1	(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or “activity monitor*” or “wearable device*” or tracker*)	14557
2	(MH "Accelerometry+")	4724
3	(MH "Fitness Trackers")	115
4	(child* or infant* or preschool* or pre-school* or toddler* or kid*)	867147
5	(MH "Child, Preschool")	183582
6	(MH "Infant+")	225387
7	(“physical activity” or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or “physical inactivity”)	353035
8	(MH "Exercise+")	100397
9	(MH "Life Style, Sedentary+")	7057
10	(MH "Pediatric Obesity")	12720
11	1 or 2 or 3	14557
12	4 or 5 or 6	867147
13	7 or 8 or 9 or 10	382717
14	11 and 12 and 13	2338
15	14 and 2009:2019	2011
	FINAL SEARCH AUGUST 16TH	**2024**

Table A.3: Initial Search Strategy conducted in PsycINFO

#	Search Terms	Results
1	**Title**: (acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or “activity monitor*” or “wearable device*” or tracker*) *OR* **Keywords**:(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or “activity monitor*” or “wearable device*” or tracker*) *OR* **Abstract**:(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or “activity monitor*” or “wearable device*” or tracker*)	11186
2	**Title**: (child* or infant* or preschool* or pre-school*) *OR* **Keywords**: (child* or infant* or preschool* or pre-school*) *OR* **Abstract**: (child* or infant* or preschool* or pre-school*)	819841
3	**Index Terms**: children	8962
4	**Index Terms**: physical activity	19968
5	**Index Terms**: physical fitness	4479
6	**Title**: (“physical activity” or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or “physical inactivity”) *OR* **Keywords**:(“physical activity” or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or “cut point*” or cut-point* or METS or “physical inactivity”)) *OR* **Abstract**: (“physical activity” or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or “cut point*” or cut-point* or METS or “physical inactivity”))	201180
7	**Index Terms**: sedentary behavior	1360
8	**Index Terms**: screen time	243
9	2 or 3	89841
10	4 or 5 or 6 or 7 or 8	208326
11	1 and 9 and 10	1017
12	11 2009:2019	865

Table A.4: Initial Search Strategy conducted in Web of Science

#	Search Terms	Results
1	TS=(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or “activity monitor*” or “wearable device*” or tracker* or “Fitness Tracker*”) [TS=Topic: searches title, abstract, author keywords and keyword plus]	102136
2	TS=(child* or infant* or preschool* or pre-schooler* or toddler* or kid*)	2501368
3	TS=(“physical activity” or fitness or exercise or “physical fitness” or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or run* or walk* or jog* or “physical conditioning” or sport*)	2935352
4	TS=(sedentary or “screen time” or “physical inactivity”)	42289
5	TS=(“pediatric obesity” or “childhood obesity”)	16688
6	#5 or #4 or #3	2956628
7	#6 and #2 and #1	4927
8	#7 and 2009:2019	4011
	FINAL SEARCH AUGUST 16TH	4085

Table A.5: Initial Search Strategy conducted in Global Health CABI

#	Search Terms	Results
1	title:(("acceleromet*" or "actigraph*" or "GT3X" or "MTI" or "CSA" or "GeneActiv" or "ActivePal" or "activity monitor*" or "wearable device*" or "tracker*" or "Fitness Track*")) OR ab:(("acceleromet*" or "actigraph*" or "GT3X" or "MTI" or "CSA" or "GeneActiv" or "ActivePal" or "activity monitor*" or "wearable device*" or "tracker*" or "Fitness Tracker*"))	11039
2	subject:("accelerometers")	158
3	title:(("child*" or "infant*" or "newborn" or "preschool*" or "pre-schooler*" or "toddler*" or "kid*")) OR ab:(("child*" or "infant*" or "newborn" or "preschool*" or "pre-schooler*" or "toddler*" or "kid*")	518344
4	subject:(("preschool children" or "children" or "infants"))	413591
5	title:(("physical activity" or "fitness" or "physical fitness" or "exercise" or "sedentary" or "MVPA" or "moderate-to-vigorous" or "vigorous" or "intensit*" or "threshold" or "cutpoint*" or "cut point*" or "cut-point*" or "METS")) OR ab:(("physical activity" or "fitness" or "physical fitness" or "exercise" or "sedentary" or "MVPA" or "moderate-to-vigorous" or "vigorous" or "intensit*" or "threshold" or "cutpoint*" or "cut point*" or "cut-point*" or "METS"))	287432
6	subject:("physical activity" OR "physical fitness")	43656
7	title:("sedentary" or "sedentary lifestyle" or "sedentary behaviour" "sedentary behavior" or "screen time" or "physical inactivity") OR ab:("sedentary" or "sedentary lifestyle" or "sedentary behaviour" "sedentary behavior" or "screen time" or "physical inactivity")	2811
8	subject:(obesity)	116521
9	5 or 6 or 7 or 8	375459
10	1 or 2	11062
11	3 or 4	581101
12	9 and 10 and 11	2255
13	12 AND (((year:(("2019" OR "2018" OR "2017" OR "2016" OR "2015" OR "2014" OR "2013" OR "2012" OR "2011" OR "2010" OR "2009")))))	1575
	FINAL SEARCH AUGUST 16TH	1473

Table A.6: Initial Search Strategy conducted in ProQuest Dissertations and Theses

#	Search Terms	Results
1	(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivPal or "activity monitor*" or "wearable device*" or tracker*)	190121
2	child* or infant* or preschool* or pre-school* or toddler* or kid*	1541451
3	MAINSUBJECT.EXACT("Preschool children")	839
4	MAINSUBJECT.EXACT("Babies")	380
5	MAINSUBJECT.EXACT("Physical fitness")	721
6	MAINSUBJECT.EXACT("Obesity")	324958
7	"physical activity" OR fitness OR exercise OR sedentary OR MVPA OR moderate-to-vigorous OR vigorous OR intensit* OR threshold OR cutpoint* OR "cut point*" OR cut-point* OR METS OR "physical inactivity" or "screen time"	1742583
8	S2 or S3 or S4	1541452
9	S5 or S6 or S7	2066989
10	S1 and S8 and S9	54851
11	S1 and S8 and S9-last 10 years	24964
	FINAL SEARCH AUGUST 16TH	3493

Google Scholar search terms: yielded 8830 results.

- ➔ First 20 pages were taken " accelerometer+preschool+physical activity"

Round 2 Searches – March 22nd, 2021

Table A.7: Initial Search Strategy conducted in Medline (via OvidSP)

#	Search Terms	Results
1	(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivPal or activity monitor* or wearable device* or tracker*).ab,kf,ti.	56741
2	exp Accelerometry/	9646
3	exp Fitness Trackers/	699
4	(child* or infant* or preschool* or pre-school* or toddler* or kid*).ab,kf,ti	2232774
5	exp Child, Preschool/	935969
6	exp Infant/	1159623
7	(physical activity or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or physical inactivity or screen time).ab,kf,ti.	1038772
8	exp Exercise/	205072
9	exp Sedentary Lifestyle/	10410
10	exp Pediatric Obesity/	9580
11	1 or 2 or 3	58841
12	4 or 5 or 6	2949504
13	7 or 8 or 9 or 10	1118385
14	11 and 12 and 13	3896
15	14 and 2019:2021	902

Table A.8: Initial Search Strategy conducted in CINAHL

#	Search Terms	Results
1	(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or "activity monitor*" or "wearable device*" or tracker*)	19564
2	(MH "Accelerometry+")	5950
3	(MH "Fitness Trackers")	218
4	(child* or infant* or preschool* or pre-school* or toddler* or kid*)	1052436
5	(MH "Child, Preschool")	215487
6	(MH "Infant+")	267398
7	("physical activity" or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or "physical inactivity")	432205
8	(MH "Exercise+")	118229
9	(MH "Life Style, Sedentary+")	8830
10	(MH "Pediatric Obesity")	15131
11	1 or 2 or 3	19564
12	4 or 5 or 6	1052436
13	7 or 8 or 9 or 10	467239
14	11 and 12 and 13	2904
15	14 and 20190801-20211231	401

Table A.9: Initial Search Strategy conducted in PsycINFO

#	Search Terms	Results
1	**Title**: (acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or "activity monitor*" or "wearable device*" or tracker*) *OR* **Keywords**: (acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or "activity monitor*" or "wearable device*" or tracker*) *OR* **Abstract**:(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or "activity monitor*" or "wearable device*" or tracker*)	13164
2	**Title**: (child* or infant* or preschool* or pre-school*) *OR* **Keywords**: (child* or infant* or preschool* or pre-school*) *OR* **Abstract**: (child* or infant* or preschool* or pre-school*)	870770
3	**Index Terms**: children	9307
4	**Index Terms**: physical activity	23316
5	**Index Terms**: physical fitness	4830
6	**Title**: ("physical activity" or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or "physical inactivity") *OR* **Keywords**:("physical activity" or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or "cut point*" or cut-point* or METS or "physical inactivity")) *OR* **Abstract**: ("physical activity" or fitness or exercise or sedentary or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or "cut point*" or cut-point* or METS or "physical inactivity"))	218497
7	**Index Terms**: sedentary behavior	1843
8	**Index Terms**: screen time	444
9	2 or 3	870770
10	4 or 5 or 6 or 7 or 8	218926
11	1 and 9 and 10	1193
12	11 2019:2021	183

Table A.9: Initial Search Strategy conducted in Web of Science

#	Search Terms	Results
1	TS=(acceleromet* or actigraph* or GT3X or MTI or CSA or GeneActiv or ActivePal or "activity monitor*" or "wearable device*" or tracker* or "Fitness Tracker*") [TS=Topic: searches title, abstract, author keywords and keyword plus]	121437
2	TS=(child* or infant* or preschool* or pre-schooler* or toddler* or kid*)	2785288
3	TS=("physical activity" or fitness or exercise or "physical fitness" or MVPA or moderate-to-vigorous or vigorous or intensit* or threshold or cutpoint* or cut point* or cut-point* or METS or run* or walk* or jog* or "physical conditioning" or sport*)	3323684
4	TS=(sedentary or "screen time" or "physical inactivity")	50798
5	TS=("pediatric obesity" or "childhood obesity")	18803
6	#5 or #4 or #3	3348457
7	#6 and #2 and #1	5863
8	#7 and 2019:2021	1333

Table A10: Initial Search Strategy conducted in Global Health CABI

#	Search Terms	Results
1	title:(("acceleromet*" or "actigraph*" or "GT3X" or "MTI" or "CSA" or "GeneActiv" or "ActivePal" or "activity monitor*" or "wearable device*" or "tracker*" or "Fitness Track*")) OR ab:(("acceleromet*" or "actigraph*" or "GT3X" or "MTI" or "CSA" or "GeneActiv" or "ActivePal" or "activity monitor*" or "wearable device*" or "tracker*" or "Fitness Tracker*"))	6572
2	subject:("accelerometers")	209
3	title:(("child*" or "infant*" or "newborn" or "preschool*" or "pre-schooler*" or "toddler*" or "kid*")) OR ab:(("child*" or "infant*" or "newborn" or "preschool*" or "pre-schooler*" or "toddler*" or "kid*")	463571
4	subject:(("preschool children" or "children" or "infants"))	381370
5	title:(("physical activity" or "fitness" or "physical fitness" or "exercise" or "sedentary" or "MVPA" or "moderate-to-vigorous" or "vigorous" or "intensit*" or "threshold" or "cutpoint*" or "cut point*" or "cut-point*" or "METS")) OR ab:(("physical activity" or "fitness" or "physical fitness" or "exercise" or "sedentary" or "MVPA" or "moderate-to-vigorous" or "vigorous" or "intensit*" or "threshold" or "cutpoint*" or "cut point*" or "cut-point*" or "METS"))	167566
6	subject:("physical activity" OR "physical fitness")	52568
7	title:("sedentary" or "sedentary lifestyle" or "sedentary behaviour" "sedentary behavior" or "screen time” or “physical inactivity”) OR ab:("sedentary" or "sedentary lifestyle" or "sedentary behaviour" "sedentary behavior" or "screen time” or “physical inactivity”)	3529
8	subject:(obesity)	130092
9	5 or 6 or 7 or 8	275027
10	1 or 2	6573
11	3 or 4	536134
12	9 and 10 and 11	1996
13	12 AND (((year:((“2021” OR “2020” OR "2019")))))	364

APPENDICES – CHAPTER 2 BIBLIOGRAPHY

**Note that reference # 363 was a thesis involving 2 studies using different methods, and were therefore counted separately, bringing the total number of references to 627.*

1. Aadl , E. J., K. (2015, 2015). Agreement of objectively measured physical activity and sedentary time in preschool children. *Preventive Medicine Reports, 2*, 635-639. https://doi.org/10.1016/j.pmedr.2015.07.009

2. Aadland, E., Andersen, L. B., Migueles, J. H., Ortega, F. B., & Kvalheim, O. M. (2020, 2020). Interpretation of associations between the accelerometry physical activity spectrum and cardiometabolic health and locomotor skills in two cohorts of children using raw, normalized, log-transformed, or compositional data. *Journal of Sports Sciences, 38*(23), 2708-2719.

3. Aadland, E., Holmøy, O. K., & Nilsen, A. K. O. (2021, 2021). The multivariate physical activity signature associated with body mass index in young children. *Preventive Medicine, 145*.

4. Aadland, E., Nilsen, A. K. O., Andersen, L. B., Rowlands, A. V., & Kvalheim, O. M. (2021, 2021). A comparison of analytical approaches to investigate associations for accelerometry-derived physical activity spectra with health and developmental outcomes in children. *Journal of Sports Sciences, 39*(4), 430-438.

5. Aadland, E., Nilsen, A. K. O., Ylvisaker, E., Johannessen, K., & Anderssen, S. A. (2020, 2020). Reproducibility of objectively measured physical activity: Reconsideration needed. *Journal of Sports Sciences, 38*(10), 1132-1139.

6. Abbott, G. H., J. Timperio, A. Salmon, J. Best, K. Hesketh, K. D. (2016, 2016). Cross-sectional and longitudinal associations between parents' and preschoolers' physical activity and television viewing: The happy study. *Journal of Physical Activity & Health, 13*(3), 269-274. https://doi.org/10.1123/jpah.2015-0136

7. Adamo, K. B. W., Niko Sebastian Grattan, Kimberly Paige Harvey, Alysha Leila Jean Naylor, Patti-Jean Barrowman, Nicolas James Goldfield, Gary Scott. (2017, 2017). Effects of a preschool intervention on physical activity and body composition. *Journal of Pediatrics, 188*, 42-49.e42.

8. Addy, C. L. T., Jennifer L. Dowda, Marsha Won, Byun Pate, Russell R. (2014, 2014). Assessing preschool children's physical activity: How many days of accelerometry measurement. *Pediatric Exercise Science, 26*(1), 103-109. https://doi.org/10.1123/pes.2013-0021

9. Ahrens, W. B., K. Siani, A. Buchecker, K. De Henauw, S. Iacoviello, L. Hebestreit, A. Krogh, V. Lissner, L. Mårild, S. Molnár, D. Moreno, L. A. Pitsiladis, Y. P. Reisch, L. Tornaritis, M. Veidebaum, T. Pigeot, I. (2011, 2011). The idefics cohort: Design, characteristics and participation in the baseline survey. *International Journal of Obesity, 35*, 53-515. https://doi.org/10.1038/ijo.2011.30

10. Alhassan, S. N., Ogechi Ghazarian, Manneh Roberts, Jasmin Mendoza, Albert Shitole, Sanyog. (2012, 2012). Effects of locomotor skill program on minority preschoolers' physical activity levels. *Pediatric Exercise Science, 24*(3), 435-449. https://doi.org/10.1123/pes.24.3.435

11. Alhassan, S. N., Ogechi Lyden, Kate Goldsby, TaShauna Mendoza, Albert. (2013, 2013). A pilot study to examine the effect of additional structured outdoor playtime on preschoolers' physical activity levels. *Child Care in Practice, 19*(1), 23-35. https://doi.org/10.1080/13575279.2012.712034

12. Alhassan, S. N., Ogechi Mendoza, Albert Shitole, Sanyog Puleo, Elaine Pfeiffer, Karin A. Whitt-Glover, Melicia C. (2016, 2016). Feasibility and effects of short activity breaks for increasing preschool-age children's physical activity levels. *Journal of School Health, 86*(7), 526-533. https://doi.org/10.1111/josh.12403

13. Alhassan, S. S. L., Christine W. Burkart, Sarah Greever, Cory J. Ahmadi, Matthew N. (2019, 2019). Feasibility of integrating physical activity into early education learning standards on preschooler's physical activity levels. *Journal of Physical Activity & Health, 16*(2), 101-107. https://doi.org/10.1123/jpah.2017-0628

14. Alonso-Martinez, A. M., Ramirez-Velez, R., Garcia-Alonso, Y., Izquierdo, M., & Garcia-Hermoso, A. (2021, 2021). Physical activity, sedentary behavior, sleep and self-regulation in spanish preschoolers during the covid-19 lockdown. *International journal of environmental research and public health, 18*(2).

15. Andersen, E., Øvreås, S., Jørgensen, K. A., Borch-Jenssen, J., & Moser, T. (2020, 2020). Children's physical activity level and sedentary behaviour in norwegian early childhood education and care: Effects of a staff-led cluster-randomised controlled trial. *BMC Public Health, 20*(1), N.PAG-N.PAG.

16. Andersen, E. B.-J., J. Ovreas, S. Ellingsen, H. Jorgensen, K. A. Moser, T. (2017, 2017). Objectively measured physical activity level and sedentary behavior in norwegian children during a week in preschool. *Preventive Medicine Reports, 7*, 130-135.

17. Annesi, J. J. S., A. E. Tennant, G. A. (2013, Dec). Effects of a cognitive-behaviorally based physical activity treatment for 4-and 5-year-old children attending us preschools. *International Journal of Behavioral Medicine, 20*(4), 562-566.

18. Annesi, J. J. S., Alice E. Tennant, Gisèle A. (2013, 2013). Effects of the start for life treatment on physical activity in primarily african american preschool children of ages 3–5 years. *Psychology, health & medicine, 18*(3), 300-309. https://doi.org/10.1080/13548506.2012.712704

19. Annesi, J. J. S., A. E. Tennant, G. A. (2013, Aug). Reducing high bmi in african american preschoolers: Effects of a behavior-based physical activity intervention on caloric expenditure. *Southern Medical Journal, 106*(8), 456-459. https://doi.org/10.1097/SMJ.0b013e3182a05bef

20. Antunes Lima, R. H. B., Simone Storino Gomes Cardoso Júnior, Crivaldo Silva, Gustavo de Farias Júnior, José Cazuza Bo Andersen, Lars Gomes de Barros, Mauro Virgilio. (2014, 2014). Influence of number of days and valid hours using accelerometry on the estimates of physical activity level in preschool children from recife, pernambuco, brazil. *Brazilian Journal of Kineanthropometry & Human Performance, 16*(2), 171-181. https://doi.org/10.5007/1980-0037.2014v16n2p171

21. Araujo-Soares, V. S., F. F. Laing, C. M. Gellert, P. Jackson, D. Speakman, J. R. (2015, 2015). Social cognitions measured in 4 to 6 year olds are predictive of objectively measured physical activity. *Psychology & Health, 30*(10), 1240-1257. https://doi.org/10.1080/08870446.2015.1041395

22. Arhab, A., Messerli-Burgy, N., Kakebeeke, T. H., Stulb, K., Zysset, A., Leeger-Aschmann, C. S., Schmutz, E. A., Meyer, A. H., Munsch, S., Kriemler, S., Jenni, O. G., & Puder, J. J. (2019, 2019). Association of physical activity with adiposity in preschoolers using different clinical adiposity measures: A cross-sectional study. *BMC Pediatrics, 19*(1).

23. Arhab, A. M.-B., Nadine Kakebeeke, Tanja H. Lanzi, Stefano Stülb, Kerstin Zysset, Annina E. Leeger-Aschmann, Claudia S. Schmutz, Einat A. Meyer, Andrea H. Munsch, Simone Kriemler, Susi Jenni, Oskar G. Puder, Jardena J. (2018, 2018). Childcare correlates of physical activity, sedentary behavior, and adiposity in preschool children: A cross-sectional analysis of the splashy study. *Journal Of Environmental & Public Health, 2018*, 1-12. https://doi.org/10.1155/2018/9157194

24. Armstrong, B., Covington, L. B., Hager, E. R., & Black, M. M. (2019, 2019). Objective sleep and physical activity using 24-hour ankle-worn accelerometry among toddlers from low-income families. *Sleep Health, 5*(5), 459-465.

25. Armstrong, B. C., Lauren B. Unick, George J. Black, Maureen M. (2019, 2019). Featured article: Bidirectional effects of sleep and sedentary behavior among toddlers: A dynamic multilevel modeling approach. *Journal of Pediatric Psychology, 44*(3), 275-285.

26. Armstrong, G. P. M., C. Lester, L. Trost, S. G. Trapp, G. Boruff, B. Al Marzooqi, M. K. Christian, H. E. (2019, 2019). Associations between the home yard and preschoolers' outdoor play and physical activity. *Public Health Research & Practice, 29*(1), 06. https://doi.org/10.17061/phrp2911907

27. Arundell, L. R., N. D. Veitch, J. Salmon, J. Hinkley, T. Timperio, A. (2013, Jun). 5-year changes in afterschool physical activity and sedentary behavior. *American Journal of Preventive Medicine, 44*(6), 605-611.

28. Bacardi-Gascón, M. R.-R., C. Woodward-Lopez, G. Crawford, P. Jiménez-Cruz, A. Bacardi-Gascón, Montserrat Reveles-Rojas, Claudia Woodward-Lopez, Gail Crawford, Patricia Jiménez-Cruz, Arturo. (2012, 2012). Assessing the validity of a physical activity questionnaire developed for parents of preschool children in mexico. *Journal of Health, Population & Nutrition, 30*(4), 439-446. https://doi.org/10.3329/jhpn.v30i4.13327

29. Ball, K. C., V. J. Timperio, A. F. Salmon, J. Crawford, D. A. (2009, 2009). Socioeconomic position and children's physical activity and sedentary behaviors: Longitudinal findings from the clan study. *Journal of Physical Activity & Health, 6*(3), 289-298. https://doi.org/10.1123/jpah.6.3.289

30. Bandini, L. G. G., J. Curtin, C. Lividini, K. Anderson, S. E. Cermak, S. A. Maslin, M. Must, A. (2013, 2013). Comparison of physical activity between children with autism spectrum disorders and typically developing children. *Autism, 17*(1), 44-54. https://doi.org/10.1177/1362361312437416

31. Barber, S. E. J., C. Hewitt, C. Ainsworth, H. R. Buckley, H. Akhtar, S. Bingham, D. D. Routen, A. C. Summerbell, C. Richardson, G. Moore, H. J. Pickett, K. E. O'Malley, C. Brierley, S. Wright, J. (2016, 2016). Assessing the feasibility of evaluating and delivering a physical activity intervention for pre-school children: A pilot randomised controlled trial. *Pilot & Feasibility Studies, 2*, 12. https://doi.org/10.1186/s40814-016-0052-4

32. Barbosa, S. C. C., D. H. Stabelini Neto, A. Elias, R. G. Oliveira, A. R. (2016, 2016). School environment, sedentary behavior and physical activity in preschool children. *Revista Paulista de Pediatria, 34*(3), 301-308.

33. Barkin, S. L. L., A. P. a, J. A. JaKa, M. M. Buchowski, M. S. Evenson, K. R. Bangdiwala, S. I. Pratt, C. French, S. A. Stevens, J. (2017, 2017). Parent's physical activity associated with preschooler activity in underserved populations. *American Journal of Preventive Medicine, 52*(4), 424-432.

34. Barnett, L. M., Hinkley, T., Okely, A. D., & Salmon, J. (2013, 2013). Child, family and environmental correlates of children's motor skill proficiency. *Journal of Science & Medicine in Sport, 16*(4), 332-336. https://doi.org/10.1016/j.jsams.2012.08.011

35. Barnett, L. M. H., T. Okely, A. D. Hesketh, K. Salmon, J. (2012, 2012). Use of electronic games by young children and fundamental movement skills? *Perceptual & Motor Skills, 114*(3), 1023-1034. https://doi.org/10.2466/10.13.PMS.114.3.1023-1034

36. Barnett, L. M. R., N. D. Salmon, J. (2015, 2015). Associations between young children's perceived and actual ball skill competence and physical activity. *Journal of Science & Medicine in Sport, 18*(2), 167-171. https://doi.org/10.1016/j.jsams.2014.03.001

37. Barnett, L. M. R., N. D. Hesketh, K. Salmon, J. (2017, 2017). Setting them up for lifetime activity: Play competence perceptions and physical activity in young children. *Journal of Science & Medicine in Sport, 20*(9), 856-860. https://doi.org/10.1016/j.jsams.2017.03.003

38. Barnett, L. M. S., J. Hesketh, K. D. (2016, 2016). More active pre-school children have better motor competence at school starting age: An observational cohort study. *BMC Public Health, 16*(1), 1068.

39. Bayer, O. J., M. Fischer, J. von Kries, R. De Bock, F. (2012, 2012). Validation and extension of a simple questionnaire to assess physical activity in pre-school children. *Public Health Nutrition, 15*(9), 1611-1619.

40. Becker, D. R. M., Megan M Loprinzi, Paul Trost, Stewart G. (2014, 2014). Physical activity, self-regulation, and early academic achievement in preschool children. *Early Education & Development, 25*(1), 56-70. https://doi.org/10.1080/10409289.2013.780505

41. Beets, M. W. B., D. Dowda, M. Pate, R. R. (2011, 2011). Compliance with national guidelines for physical activity in u.S. Preschoolers: Measurement and interpretation. *Pediatrics, 127*(4), 658-664.

42. Bekelman, T. A., Sauder, K. A., Rockette-Wagner, B., Glueck, D. H., & Dabelea, D. (2020, 2020). Sociodemographic predictors of adherence to national diet and physical activity guidelines at age 5 years: The healthy start study. *American Journal of Health Promotion*.

43. Belanger, M., Dugas, C., Perron, J., Ruchat, S.-M., Weisnagel, S. J., Marc, I., Tchernof, A., & Robitaille, J. (2019, 2019). Association between lifestyle habits and adiposity values among children exposed and unexposed to gestational diabetes mellitus in utero. *Diabetes & metabolic syndrome, 13*(5), 2947-2952.

44. Benjamin-Neelon, S. E., Bai, J., Ostbye, T., Neelon, B., Pate, R. R., & Crainiceanu, C. (2020, 2020). Physical activity and adiposity in a racially diverse cohort of us infants. *Obesity (Silver Spring, Md.), 28*(3), 631-637.

45. Berglind, D. H., L. Tynelius, P. Rasmussen, F. (2017, 2017). Levels and patterns of objectively measured physical activity and sedentary time in 4-year-old swedish children. *Journal of Physical Activity & Health, 14*(2), 117-122. https://doi.org/10.1123/jpah.2016-0250

46. Berglind, D. L., R. Tynelius, P. Brooke, H. L. (2018, 2018). Cross-sectional and prospective associations of meeting 24-h movement guidelines with overweight and obesity in preschool children. *Pediatric Obesity, 13*(7), 442-449. https://doi.org/10.1111/ijpo.12265

47. Berglind, D. T., P. (2017, 2017). Objectively measured physical activity patterns, sedentary time and parent-reported screen-time across the day in four-year-old swedish children. *BMC Public Health, 18*(1), 69.

48. Bergqvist-Noren, L., Johansson, E., Xiu, L. J., Hagman, E., Marcus, C., & Hagstromer, M. (2020, 2020). Patterns and correlates of objectively measured physical activity in 3-year-old children. *BMC Pediatrics, 20*(1).

49. Bezerra, T. A., Clark, C. C. T., De Souza, A. N., Fortes, L. D., Mota, J., Duncan, M. J., & Martins, C. M. D. (2020, 2020). 24 movement behaviour and executive function in preschoolers: A compositional and isotemporal reallocation analysis. *European Journal of Sport Science*.

50. Bielemann, R. M. C., A. M. Reichert, F. F. Domingues, M. R. Gigante, D. P. (2013, 2013). Objectively measured physical activity in children from a southern brazilian city: A population-based study. *Journal of Physical Activity & Health, 10*(8), 1145-1152. https://doi.org/10.1123/jpah.10.8.1145

51. Bielemann, R. M. R., F. F. Paniz, V. M. Gigante, D. P. (2011, 2011). Validation of the netherlands physical activity questionnaire in brazilian children. *International Journal of Behavioral Nutrition & Physical Activity, 8*, 45. https://doi.org/10.1186/1479-5868-8-45

52. Bingham, D. D. C., Silvia Clemes, Stacy A. Routen, Ash C. Moore, Helen J. Barber, Sally E. (2016, 2016). 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, 34*(20), 2005-2010.

53. Bingham, D. D. C., P. J. Clemes, S. A. Costa, S. Santorelli, G. Griffiths, P. Barber, S. E. (2016, Jun). Reliability and validity of the early years physical activity questionnaire (ey-paq). *Sports, 4*(2). https://doi.org/10.3390/sports4020030

54. Bisson, M. T., Florence Pronovost, Etienne Julien, Anne-Sophie Marc, Isabelle. (2019, 2019). Accelerometry to measure physical activity in toddlers: Determination of wear time requirements for a reliable estimate of physical activity. *Journal of Sports Sciences, 37*(3), 298-305.

55. Black, M. M., Hager, E. R., Wang, Y., Hurley, K. M., Latta, L. W., Candelaria, M., & Caulfield, L. E. (2021, 2021). Toddler obesity prevention: A two-generation randomized attention-controlled trial. *Maternal & Child Nutrition, 17*(1), 1-16.

56. Blaes, A. B., G. Van Praagh, E. Berthoin, S. (2011, May). Physical activity patterns in french youth-from childhood to adolescence-monitored with high-frequency accelerometry. *American Journal of Human Biology, 23*(3), 353-358. https://doi.org/10.1002/ajhb.21142

57. Bonis, M. L., M. Ward, D. Tseng, T. S. Clesi, A. Sothern, M. (2014, 2014). Improving physical activity in daycare interventions. *Childhood Obesity, 10*(4), 334-341. https://doi.org/10.1089/chi.2014.0040

58. Bonvin, A. B., Jérôme Kakebeeke, Tanja H. Kriemler, Susi Longchamp, Anouk Marques-Vidal, Pedro Puder, Jardena J. (2012, 2012). Weight status and gender-related differences in motor skills and in child care - based physical activity in young children. *BMC Pediatrics, 12*(1), 23-23. https://doi.org/10.1186/1471-2431-12-23

59. Borkhoff, C. M. H., Liane D. Anderson, Laura N. Tremblay, Mark S. Maguire, Jonathon L. Parkin, Patricia C. Birken, Catherine S. (2015, 2015). Objectively measured physical activity of young canadian children using accelerometry. *Applied Physiology, Nutrition & Metabolism, 40*(12), 1302-1308. https://doi.org/10.1139/apnm-2015-0164

60. Bornstein, D. B. B., M. W. Byun, W. Welk, G. Bottai, M. Dowda, M. Pate, R. Bornstein, Daniel B. Beets, Michael W. Byun, Wonwoo Welk, Greg Bottai, Matteo Dowda, Marsha Pate, Russell. (2011, 2011). Equating accelerometer estimates of moderate-to-vigorous physical activity: In search of the rosetta stone. *Journal of Science & Medicine in Sport, 14*(5), 404-410. https://doi.org/10.1016/j.jsams.2011.03.013

61. Brandes, B., Buck, C., Wright, M. N., Pischke, C. R., & Brandes, M. (2020, 2020). Impact of "jolinchenkids-fit and healthy in daycare" on children's objectively measured physical activity: A cluster-controlled study. *Journal of Physical Activity & Health, 17*(10), 1025-1033.

62. Brasholt, M. B., F. Bisgaard, H. (2010, 2010). Physical activity in young children is reduced with increasing bronchial responsiveness. *Journal of Allergy & Clinical Immunology, 125*(5), 1007-1012.

63. Brasholt, M. C., B. Kreiner-Moller, E. Vahlkvist, S. Sinding, M. Bisgaard, H. (2013, 2013). Objective assessment of levels and patterns of physical activity in preschool children. *Pediatric Research, 74*(3), 333-338.

64. Brian, A. T., S. Shortt, C. Pennell, A. Sacko, R. (2019, Jan). Predictors of physical activity for preschool children with and without disabilities from socioeconomically disadvantaged settings. *Adapted Physical Activity Quarterly, 36*(1), 77-90. https://doi.org/10.1123/apaq.2017-0191

65. Bringolf-Isler, B. K., S. Mader, U. Dossegger, A. Hofmann, H. Puder, J. J. Braun-Fahrl er, C. (2014, 2014). Relationship between the objectively-assessed neighborhood area and activity behavior in swiss youth. *Preventive Medicine Reports, 1*, 14-20.

66. Bringolf-Isler, B. M., U. Dossegger, A. Hofmann, H. Puder, J. J. Braun-Fahrl er, C. Kriemler, S. (2015, 2015). Regional differences of physical activity and sedentary behaviour in swiss children are not explained by socio-demographics or the built environment. *International Journal of Public Health, 60*(3), 291-300.

67. Brouwer, S. I., Stolk, R. P., & Corpeleijn, E. (2019, 2019). Later achievement of infant motor milestones is related to lower levels of physical activity during childhood: The gecko drenthe cohort. *BMC Pediatrics, 19*(1).

68. Brouwer, S. I. K., L. K. Kors, L. Sijtsma, A. Sauer, P. J. J. Renders, C. M. Corpeleijn, E. (2018, 2018). Parental physical activity is associated with objectively measured physical activity in young children in a sex-specific manner: The gecko drenthe cohort. *BMC Public Health, 18*(1), 1033.

69. Buck, C., Eiben, G., Lauria, F., Konstabel, K., Page, A., Ahrens, W., Pigeot, I., & Consortia, I. I. F. (2019, 2019). Urban moveability and physical activity in children: Longitudinal results from the idefics and i.Family cohort. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1).

70. Buck, C. K., T. Tkaczick, T. Konstabel, K. Pigeot, I. (2015, 2015). Assessing opportunities for physical activity in the built environment of children: Interrelation between kernel density and neighborhood scale. *International Journal of Health Geographics [Electronic Resource], 14*, 35. https://doi.org/10.1186/s12942-015-0027-3

71. Buck, C. T., T. Pitsiladis, Y. De Bourdehaudhuij, I. Reisch, L. Ahrens, W. Pigeot, I. (2015, 2015). Objective measures of the built environment and physical activity in children: From walkability to moveability. *Journal of Urban Health, 92*(1), 24-38.

72. Bulten, R., Brown, D., Rodriguez, C., & Cairney, J. (2020). *Association of sedentary behaviour on internalizing problems in children with and without motor coordination problems*. Elsevier Science.

73. Bundgaard, A. K. F. A., J. Pedersen, N. S. Bilenberg, N. (2018, Oct). Disturbed sleep and activity in toddlers with early signs of attention deficit hyperactivity disorder (adhd). *Journal of Sleep Research, 27*(5), e12686. https://doi.org/10.1111/jsr.12686

74. Bürgi, F. M., Ursina Niederer, Iris Ebenegger, Vincent Marques-Vidal, Pedro Granacher, Urs Kriemler, Susi Puder, Jardena J. (2010, 2010). Socio-cultural determinants of adiposity and physical activity in preschool children: A cross-sectional study. *BMC Public Health, 10*(1), 733-733. https://doi.org/Artn 733 10.1186/1471-2458-10-733

75. Burgi, F. M., U. Granacher, U. Schindler, C. Marques-Vidal, P. Kriemler, S. Puder, J. J. (2011). Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: A cross-sectional and longitudinal study (ballabeina). *International Journal of Obesity, 35*(7), 937-944. https://doi.org/10.1038/ijo.2011.54

76. Butte, N. F. P., Maurice R. Wilson, Theresa A. Liu, Yan Wong, William W. Adolph, Anne L. Zakeri, Issa F. (2016, 2016). Role of physical activity and sleep duration in growth and body composition of preschool-aged children. *Obesity (19307381), 24*(6), 1328-1335.

77. Butte, N. F. W., William W. Jong Soo, Lee Adolph, Anne L. Puyau, Maurice R. Zakeri, Issa F. (2014, 2014). Prediction of energy expenditure and physical activity in preschoolers. *Medicine & Science in Sports & Exercise, 46*(6), 1216-1226. https://doi.org/10.1249/MSS.0000000000000209

78. Byun, W. (2013). *Sedentary behavior in preschool children: Studies of reliability, level, and effect of objectively measured sedentary behavior* ProQuest Information & Learning]. US.

79. Byun, W. B., S. N. Pate, R. R. (2013, 2013). Objectively measured sedentary behavior in preschool children: Comparison between montessori and traditional preschools. *International Journal of Behavioral Nutrition & Physical Activity, 10*, 2. https://doi.org/10.1186/1479-5868-10-2

80. Byun, W. B., M. W. Pate, R. R. (2015, 2015). Sedentary behavior in preschoolers: How many days of accelerometer monitoring is needed? *International Journal of Environmental Research & Public Health [Electronic Resource], 12*(10), 13148-13161.

81. Byun, W. D., M. Pate, R. R. (2011, 2011). Correlates of objectively measured sedentary behavior in us preschool children. *Pediatrics, 128*(5), 937-945.

82. Byun, W. K., Y. Brusseau, T. A. (2018, 2018). The use of a fitbit device for assessing physical activity and sedentary behavior in preschoolers. *Journal of Pediatrics, 199*, 35-40. https://doi.org/10.1016/j.jpeds.2018.03.057

83. Byun, W. L., J. Pate, R. R. (2013, 2013). Association between objectively measured sedentary behavior and body mass index in preschool children. *International Journal of Obesity, 37*(7), 961-965.

84. Byun, W. L., E. Y. Brusseau, T. A. (2018, 2018). Feasibility and effectiveness of a wearable technology-based physical activity intervention in preschoolers: A pilot study. *International Journal of Environmental Research & Public Health [Electronic Resource], 15*(9), 23.

85. Cadenas-Sanchez, C. H., P. Henriksson, H. Delisle Nystrom, C. Pomeroy, J. Ruiz, J. R. Ortega, F. B. Lof, M. (2017, 2017). Parental body mass index and its association with body composition, physical fitness and lifestyle factors in their 4-year-old children: Results from the ministop trial. *European Journal of Clinical Nutrition, 71*(10), 1200-1205. https://doi.org/10.1038/ejcn.2017.62

86. Caldwell, H. A. P., N. A. King-Dowling, S. Di Cristofaro, N. A. Cairney, J. Timmons, B. W. (2016, 2016). Tracking of physical activity and fitness during the early years. *Applied Physiology, Nutrition, & Metabolism = Physiologie Appliquee, Nutrition et Metabolisme, 41*(5), 504-510. https://doi.org/10.1139/apnm-2015-0338

87. Caldwell, H. A. T. D. C., N. A. Proudfoot, N. A. King-Dowling, S. Timmons, B. W. (2016, 2016). From early years to school-aged years: Compliance with canadian physical activity guidelines...2016 north american society for pediatric exercise medicine (naspem) biennial meeting, knoxville, tennessee. *Pediatric Exercise Science, 28*, 49-49. https://doi.org/10.1123/pes.2016.0242

88. Cameron, A. J. B., Kylie Hesketh, Kylie D. McNaughton, Sarah A. Salmon, Jo Crawford, David A. Lioret, S rine Campbell, Karen J. (2014, 2014). Variation in outcomes of the melbourne infant, feeding, activity and nutrition trial (infant) program according to maternal education and age. *Preventive Medicine, 58*, 58-63.

89. Campbell, K. J. L., S rine McNaughton, Sarah A. Crawford, David A. Salmon, Jo Ball, Kylie McCallum, Zoe Gerner, Bibi E. Spence, Alison C. Cameron, Adrian J. Hnatluk, Jill A. Ukoumunne, Obioha C. Gold, Lisa Abbott, Gavin Hesketh, Kylie D. (2013, 2013). A parent-focused intervention to reduce infant obesity risk behaviors: A randomized trial. *Pediatrics, 131*(4), 652-660.

90. Cantell, M. C., S. G. Dewey, D. (2012, 2012). Daily physical activity in young children and their parents: A descriptive study. *Paediatrics & Child Health, 17*(3), e20-24. https://doi.org/10.1093/pch/17.3.e20

91. Cardon, G. L., V. Smits, D. De Bourdeaudhuij, I. (2009, 2009). Promoting physical activity at the pre-school playground: The effects of providing markings and play equipment. *Preventive Medicine, 48*(4), 335-340.

92. Carson, V., Adamo, K. B., Ogden, N., Goldfield, G. S., Okely, A. D., Kuzik, N., Crozier, M., Hunter, S., & Predy, M. (2020, 2020). Sedentary time and physical activity associations between child care educators and children. *American Journal of Preventive Medicine, 58*(4), e105-e111.

93. Carson, V., Langlois, K., & Colley, R. (2020, 2020). Associations between parent and child sedentary behaviour and physical activity in early childhood. *Health Reports, 31*(2), 3-10.

94. Carson, V. C., D. Ogden, N. Harber, V. Kuzik, N. (2015, Nov). Short-term influence of revised provincial accreditation standards on physical activity, sedentary behavior, and weight status in alberta, canada child care centers. *Early Childhood Education Journal, 43*(6), 459-465. https://doi.org/10.1007/s10643-015-0688-3

95. Carson, V. E., Victor E. Tamana, Sukhpreet K. Chikuma, Joyce Lefebvre, Diana L. Azad, Meghan B. Moraes, Theo J. Subbarao, Padmaja Becker, Allan B. Turvey, Stuart E. Sears, Malcolm R. hane, Piush J. (2019, 2019). Associations between meeting the canadian 24-hour movement guidelines for the early years and behavioral and emotional problems among 3-year-olds. *Journal of Science & Medicine in Sport, 22*(7), 797-802. https://doi.org/10.1016/j.jsams.2019.01.003

96. Carson, V. K., N. (2017, 2017). Demographic correlates of screen time and objectively measured sedentary time and physical activity among toddlers: A cross-sectional study. *BMC Public Health, 17*(1), 187.

97. Carson, V. L., E. Y. Hesketh, K. D. Hunter, S. Kuzik, N. Predy, M. Rhodes, R. E. Rinaldi, C. M. Spence, J. C. Hinkley, T. (2019, 2019). Physical activity and sedentary behavior across three time-points and associations with social skills in early childhood. *BMC Public Health, 19*(1), 27.

98. Carson, V. R., A. A. Wiebe, S. A. (2017, Oct). Associations of subjectively and objectively measured sedentary behavior and physical activity with cognitive development in the early years. *Mental Health and Physical Activity, 13*, 1-8. https://doi.org/10.1016/j.mhpa.2017.05.003

99. Carson, V. S., Jo Crawford, David Hinkley, Trina Hesketh, Kylie D. (2016, 2016). Longitudinal levels and bouts of objectively measured sedentary time among young australian children in the happy study. *Journal of Science & Medicine in Sport, 19*(3), 232-236. https://doi.org/10.1016/j.jsams.2015.01.009

100. Carson, V. T., Mark S. Chastin, Sebastien F. M. (2017, 2017). Cross-sectional associations between sleep duration, sedentary time, physical activity, and adiposity indicators among canadian preschool-aged children using compositional analyses. *BMC Public Health, 17*, 123-131. https://doi.org/ARTN 848 10.1186/s12889-017-4852-0

101. Carter, P. J. T., B. J. Williams, S. M. Taylor, R. W. (2011, 2011). Longitudinal analysis of sleep in relation to bmi and body fat in children: The flame study. *Bmj, 342*, d2712.

102. Carver, A. T., A. F. Hesketh, K. D. Ridgers, N. D. Salmon, J. L. Crawford, D. A. (2011, 2011). How is active transport associated with children's and adolescents' physical activity over time? *International Journal of Behavioral Nutrition & Physical Activity, 8*, 126. https://doi.org/10.1186/1479-5868-8-126

103. Cerin, E. B., Tom Barnett, Anthony Butte, Nancy Hughes, Sheryl Lee, Rebecca E. Mendoza, Jason A. Thompson, Debbe O'Connor, Teresia Margareta. (2016, 2016). Places where preschoolers are (in)active: An observational study on latino preschoolers and their parents using objective measures. *International Journal of Behavioral Nutrition & Physical Activity, 13*, 1-12. https://doi.org/ARTN 29 10.1186/s12966-016-0355-0

104. Chai, L. K., Rice-McNeil, K., & Trost, S. G. (2020, 2020). Patterns and correlates of sedentary behavior in children attending family child care. *International journal of environmental research and public health, 17*(2).

105. Chakravarthi, S. (2010). *Preschool teachers' beliefs and practices of outdoor play and outdoor environments* ProQuest Information & Learning]. US.

106. Chalcarz, W. M., S. (2016, 2016). Modifying dietary intake and physical activity in preschool children and its influence on nutritional status and physical fitness - methodology of an intervention study in polish preschoolers. *New Medicine, 20*(1), 3-7. https://doi.org/10.5604/14270994.1197169

107. Chang, Z., Wang, S., & Zhang, X. (2020, 2020). Seasonal variations in physical activity and sedentary behavior among preschool children in a central china city. *American journal of human biology : the official journal of the Human Biology Council, 32*(6), e23406.

108. Chaput, J. P. C., R. C. Aubert, S. Carson, V. Janssen, I. Roberts, K. C. Tremblay, M. S. (2017, 2017). Proportion of preschool-aged children meeting the canadian 24-hour movement guidelines and associations with adiposity: Results from the canadian health measures survey. *BMC Public Health, 17*, 829.

109. Chen, B., Bernard, J. Y., Padmapriya, N., Ning, Y., Cai, S., Lanca, C., Tan, K. H., Yap, F., Chong, Y.-S., Shek, L., Godfrey, K. M., Saw, S. M., Chan, S.-Y., Eriksson, J. G., Tan, C. S., & Muller-Riemenschneider, F. (2020, 2020). Associations between early-life screen viewing and 24 hour movement behaviours: Findings from a longitudinal birth cohort study. *The Lancet. Child & adolescent health, 4*(3), 201-209.

110. Chen, B., Waters, C. N., Compier, T., Uijtdewilligen, L., Petrunoff, N. A., Lim, Y. W., van Dam, R., & Muller-Riemenschneider, F. (2020, 2020). Understanding physical activity and sedentary behaviour among preschool-aged children in singapore: A mixed-methods approach. *BMJ Open, 10*(4), e030606.

111. Chen, B. Z., Bernard, J. Y., Padmapriya, N., Yao, J. L., Goh, C., Tan, K. H., Yap, F., Chong, Y. S., Shek, L., Godfrey, K. M., Chan, S. Y., Eriksson, J. G., & Muller-Riemenschneider, F. (2019, 2019). Socio-demographic and maternal predictors of adherence to 24-hour movement guidelines in singaporean children. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1).

112. Chen, C., Ahlqvist, V. H., Henriksson, P., Magnusson, C., & Berglind, D. (2020, 2020). Preschool environment and preschool teacher's physical activity and their association with children's activity levels at preschool. *PLoS One, 15*(10).

113. Chen, C., Sellberg, F., Ahlqvist, V. H., Neovius, M., Christiansen, F., & Berglind, D. (2020, 2020). Associations of participation in organized sports and physical activity in preschool children: A cross-sectional study. *BMC Pediatrics, 20*(1), 1-9.

114. Cheng, L., Pohlabeln, H., Ahrens, W., Lauria, F., Veidebaum, T., Chadjigeorgiou, C., Molnar, D., Eiben, G., Michels, N., Moreno, L. A., Page, A. S., Pitsiladis, Y., Hebestreit, A., Idefics, & Consortia, I. F. (2020, 2020). Cross-sectional and longitudinal associations between physical activity, sedentary behaviour and bone stiffness index across weight status in european children and adolescents. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1).

115. Chesham, R. A. B., Josephine N. Sweeney, Emma L. Ryde, Gemma C. Gorely, Trish Brooks, Naomi E. Moran, Colin N. (2018, 2018). The daily mile makes primary school children more active, less sedentary and improves their fitness and body composition: A quasi-experimental pilot study. *BMC Medicine, 16*(1), N.PAG-N.PAG. https://doi.org/ARTN 64 10.1186/s12916-018-1049-z

116. Christian, H., Lester, L., Trost, S. G., Trapp, G., Schipperijn, J., Boruff, B., Maitland, C., Jeemi, Z., Rosenberg, M., Barber, P., & Eslick, H. (2019, 2019). Shade coverage, ultraviolet radiation and children's physical activity in early childhood education and care. *International Journal of Public Health, 64*(9), 1325-1333.

117. Chuang, R.-J. (2015). *Increasing moderate-to-vigorous physical activity among preschool children during school hours* ProQuest Information & Learning]. US.

118. Clark, C. C. T., Duncan, M. J., Eyre, E. L. J., Stratton, G., Garcia-Masso, X., & Estevan, I. (2020, 2020). Profiling movement behaviours in pre-school children: A self-organised map approach. *Journal of Sports Sciences, 38*(2), 150-158.

119. Clark, C. C. T. B., Claire M. Swindell, Nils J. Holton, Mark D. Bingham, Daniel D. Collings, Paul J. Barber, Sally E. Summers, Huw D. Mackintosh, Kelly A. Stratton, Gareth. (2018, 2018). Profiling movement and gait quality characteristics in pre-school children. *Journal of Motor Behavior, 50*(5), 557-565.

120. Cleland , V. T., A. Salmon, J. Hume, C. Telford, A. Crawford, D. (2011, 2011). A longitudinal study of the family physical activity environment and physical activity among youth. *American Journal of Health Promotion, 25*(3), 159-167. https://doi.org/10.4278/ajhp.090303-QUAN-93

121. Clevenger, K. A., Grady, S. C., Erickson, K., & Pfeiffer, K. A. (2020, 2020). Use of a spatiotemporal approach for understanding preschoolers' playground activity. *Spatial and Spatio-Temporal Epidemiology, 35*, 100376.

122. Clevenger, K. A., McKee, K. L., & Pfeiffer, K. A. (2021, 2021). Classroom location, activity type, and physical activity during preschool children's indoor free-play. *Early Childhood Education Journal*, No Pagination Specified-No Pagination Specified.

123. Cliff, D. P. M., Jade Vella, Stewart A. Howard, Steven J. Santos, Rute Batterham, Marijka Melhuish, Edward Okely, Anthony D. de Rosnay, Marc. (2017, 2017). Adherence to 24-hour movement guidelines for the early years and associations with social-cognitive development among australian preschool children. *BMC Public Health, 17*, 207-215. https://doi.org/ARTN 857 10.1186/s12889-017-4858-7

124. Cliff, D. P. O., A. D. Smith, L. M. McKeen, K. (2009, 2009). Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science, 21*(4), 436-449. https://doi.org/10.1123/pes.21.4.436

125. Colley, R. C., Christidis, T., Michaud, I., Tjepkema, M., & Ross, N. A. (2019, 2019). An examination of the associations between walkable neighbourhoods and obesity and self-rated health in canadians. *Health Reports, 30*(9), 14-24.

126. Colley, R. C., Christidis, T., Michaud, I., Tjepkema, M., & Ross, N. A. (2019, 2019). The association between walkable neighbourhoods and physical activity across the lifespan. *Health Reports, 30*(9), 3-13.

127. Colley, R. C. G., D. Adamo, K. B. Carson, V. Janssen, I. Timmons, B. W. Tremblay, M. S. (2013, 2013). Physical activity and sedentary behavior during the early years in canada: A cross-sectional study. *International Journal of Behavioral Nutrition & Physical Activity, 10*, 54. https://doi.org/10.1186/1479-5868-10-54

128. Colley, R. C. H., A. Grattan, K. P. Adamo, K. B. (2014, 2014). Impact of accelerometer epoch length on physical activity and sedentary behaviour outcomes for preschool-aged children. *Health Reports, 25*(1), 3-9.

129. Collings, P. J., Dogra, S. A., Costa, S., Bingham, D. D., & Barber, S. E. (2020, 2020). Objectively-measured sedentary time and physical activity in a bi-ethnic sample of young children: Variation by socio-demographic, temporal and perinatal factors. *BMC Public Health, 20*(1).

130. Collings, P. J. B., S. Ridgway, C. L. Harvey, N. C. Godfrey, K. M. Inskip, H. M. Cooper, C. Wareham, N. J. Ekelund, U. (2013, 2013). Physical activity intensity, sedentary time, and body composition in preschoolers. *American Journal of Clinical Nutrition, 97*(5), 1020-1028.

131. Collings, P. J. B., S. Bingham, D. D. Costa, S. West, J. McEachan, R. R. C. Wright, J. Barber, S. E. (2017, 2017). Physical activity, sedentary time, and fatness in a biethnic sample of young children. *Medicine & Science in Sports & Exercise, 49*(5), 930-938. https://doi.org/10.1249/MSS.0000000000001180

132. Cooper, A. R. G., Anna Page, Angie S. Sherar, Lauren B. Esliger, Dale W. van Sluijs, Esther M. F. Andersen, Lars Bo Anderssen, Sigmund Cardon, Greet Davey, Rachel Froberg, Karsten Hallal, Pedro Janz, Kathleen F. Kordas, Katarzyna Kreimler, Susi Pate, Russ R. Puder, Jardena J. Reilly, John J. Salmon, Jo Sardinha, Luis B. (2015, 2015). Objectively measured physical activity and sedentary time in youth: The international children's accelerometry database (icad). *International Journal of Behavioral Nutrition & Physical Activity, 12*, 1-10. https://doi.org/10.1186/s12966-015-0274-5

133. Copel , K. A. K., J. C. Kalkwarf, H. J. (2016, 2016). Child care center characteristics associated with preschoolers' physical activity. *American Journal of Preventive Medicine, 50*(4), 470-479. https://doi.org/10.1016/j.amepre.2015.08.028

134. Corder, K. v. S., E. M. Wright, A. Whincup, P. Wareham, N. J. Ekelund, U. (2009, 2009). Is it possible to assess free-living physical activity and energy expenditure in young people by self-report? *American Journal of Clinical Nutrition, 89*(3), 862-870.

135. Costa, S. B., Sally E. Cameron, Noël Clemes, Stacy A. (2015, 2015). The objective measurement of physical activity and sedentary behaviour in 2-3 year olds and their parents: A cross-sectional feasibility study in the bi-ethnic born in bradford cohort. *BMC Public Health, 15*(1), 1-10. https://doi.org/ARTN 1109 10.1186/s12889-015-2481-z

136. Crane, J. R. N., P. J. Cook, R. Temple, V. A. (2015, 2015). Do perceptions of competence mediate the relationship between fundamental motor skill proficiency and physical activity levels of children in kindergarten? *Journal of Physical Activity & Health, 12*(7), 954-961. https://doi.org/10.1123/jpah.2013-0398

137. Crane, J. R. N., P. J. Temple, V. A. (2018, Oct). The physical activity and sedentary behaviour patterns of children in kindergarten and grade 2. *Children-Basel, 5*(10). https://doi.org/10.3390/children5100131

138. Crotti, M., Rudd, J. R., Roberts, S., Boddy, L. M., Davies, K. F., O'Callaghan, L., Utesch, T., & Foweather, L. (2021, 2021). Effect of linear and nonlinear pedagogy physical education interventions on children's physical activity: A cluster randomized controlled trial (sample-pe). *Children, 8*(1), 1-21.

139. Davison, K. K. J., J. M. Li, K. Kranz, S. Lawson, H. A. (2013, 2013). A childhood obesity intervention developed by families for families: Results from a pilot study. *International Journal of Behavioral Nutrition & Physical Activity, 10*, 3. https://doi.org/10.1186/1479-5868-10-3

140. Dawson-Hahn, E. E. F., M. D. Mendoza, J. A. (2015, 2015). Correlates of physical activity in latino preschool children attending head start. *Pediatric Exercise Science, 27*(3), 372-379.

141. De Bock, F. G., B. Raat, H. Fischer, J. E. Renz-Polster, H. (2013, 2013). A participatory physical activity intervention in preschools: A cluster randomized controlled trial. *American Journal of Preventive Medicine, 45*(1), 64-74.

142. De Craemer, M., Verbestel, V., Cardon, G., Androutsos, O., Manios, Y., & Chastin, S. (2020, 2020). Correlates of meeting the physical activity, sedentary behavior, and sleep guidelines for the early years among belgian preschool children: The toybox-study. *International journal of environmental research and public health, 17*(19).

143. De Craemer, M. D. D., E. Verloigne, M. De Bourdeaudhuij, I. Manios, Y. Cardon, G. ToyBox-study, group. (2014, 2014). The effect of a kindergarten-based, family-involved intervention on objectively measured physical activity in belgian preschool boys and girls of high and low ses: The toybox-study. *International Journal of Behavioral Nutrition & Physical Activity, 11*(1), 38. https://doi.org/10.1186/1479-5868-11-38

144. De Craemer, M. D. D., Ellen De Bourdeaudhuij, Ilse Verloigne, Maïté Manios, Yannis Cardon, Greet. (2015, 2015). The translation of preschoolers' physical activity guidelines into a daily step count target. *Journal of Sports Sciences, 33*(10), 1051-1057.

145. De Craemer, M. D. D., E. Santos-Lozano, A. Verloigne, M. De Bourdeaudhuij, I. Deforche, B. Cardon, G. (2015, 2015). Validity of the omron pedometer and the actigraph step count function in preschoolers. *Journal of Science & Medicine in Sport, 18*(3), 289-293. https://doi.org/10.1016/j.jsams.2014.06.001

146. De Craemer, M. D. D., Ellen Verloigne, Maïté De Bourdeaudhuij, Ilse Manios, Yannis Cardon, Greet. (2016, 2016). The effect of a cluster randomised control trial on objectively measured sedentary time and parental reports of time spent in sedentary activities in belgian preschoolers: The toybox-study. *International Journal of Behavioral Nutrition & Physical Activity, 13*, 1-17. https://doi.org/10.1186/s12966-015-0325-y

147. De Craemer, M. M., D. Androutsos, O. Manios, Y. Cardon, G. (2018, 2018). Compliance with 24-h movement behaviour guidelines among belgian pre-school children: The toybox-study. *International Journal of Environmental Research & Public Health [Electronic Resource], 15*(10), 03.

148. De Decker, E. D. C., M. Santos-Lozano, A. Van Cauwenberghe, E. De Bourdeaudhuij, I. Cardon, G. (2013, 2013). Validity of the activpaltm and the actigraph monitors in preschoolers. *Medicine & Science in Sports & Exercise, 45*(10), 2002-2011. https://doi.org/10.1249/MSS.0b013e318292c575

149. de Moraes, A. C. C., H. B. Siani, A. Barba, G. Veidebaum, T. Tornaritis, M. Molnar, D. Ahrens, W. Wirsik, N. De Henauw, S. Marild, S. Lissner, L. Konstabel, K. Pitsiladis, Y. Moreno, L. A. consortium, Idefics. (2015, 2015). Incidence of high blood pressure in children - effects of physical activity and sedentary behaviors: The idefics study: High blood pressure, lifestyle and children. *International Journal of Cardiology, 180*, 165-170.

150. De Moraes, A. C. F., Nascimento-Ferreira, M. V., Forjaz, C. L. D., Aristizabal, J. C., Azzaretti, L., Nascimento, W. V., Miguel-Berges, M. L., Skapino, E., Delgado, C., Moreno, L. A., & Carvalho, H. B. (2020, 2020). Reliability and validity of a sedentary behavior questionnaire for south american pediatric population: Saycare study. *BMC Medical Research Methodology, 20*(1).

151. Delaney, S. L. M., P. Johnson, D. B. (2014, 2014). Physical activity levels in family child care homes. *Journal of Physical Activity & Health, 11*(7), 1362-1366. https://doi.org/10.1123/jpah.2012-0297

152. Delisle Nystrom, C., Alexandrou, C., Henstrom, M., Nilsson, E., Okely, A. D., Wehbe El Masri, S., & Lof, M. (2020, 2020). International study of movement behaviors in the early years (sunrise): Results from sunrise sweden's pilot and covid-19 study. *International journal of environmental research and public health, 17*(22).

153. Delisle Nystrom, C. P., J. Henriksson, P. Forsum, E. Ortega, F. B. Maddison, R. Migueles, J. H. Lof, M. (2017, 2017). Evaluation of the wrist-worn actigraph wgt3x-bt for estimating activity energy expenditure in preschool children. *European Journal of Clinical Nutrition, 71*(10), 1212-1217. https://doi.org/10.1038/ejcn.2017.114

154. Dias, K. I. W., J. Jago, R. Cardon, G. Davey, R. Janz, K. F. Pate, R. R. Puder, J. J. Reilly, J. J. Kipping, R. (2019, 2019). International comparison of the levels and potential correlates of objectively measured sedentary time and physical activity among three-to-four-year-old children. *International Journal of Environmental Research & Public Health [Electronic Resource], 16*(11), 31.

155. Djafarian, K. S., J. R. Stewart, J. D, M. Jackson. (2013, 2013). Familial resemblance of body composition, physical activity, and resting metabolic rate in pre-school children. *Reports of Biochemistry & Molecular Biology, 2*(1), 1-15.

156. Dlugonski, D., DuBose, K. D., Habeeb, C. M., & Rider, P. (2020, 2020). Physical activity coparticipation among parent–young-child dyads. *Pediatric Exercise Science, 32*(3), 132-139.

157. Dlugonski, D. D., K. D. Rider, P. (2017, 2017). Accelerometer-measured patterns of shared physical activity among mother-young child dyads. *Journal of Physical Activity & Health, 14*(10), 808-814. https://doi.org/10.1123/jpah.2017-0028

158. Dolinsky, D. H. B., R. J. Evenson, K. R. Siega-Riz, A. M. Ostbye, T. Dolinsky, Diana H. Brouwer, Rebecca J. Namenek Evenson, Kelly R. Siega-Riz, Anna Maria Østbye, Truls. (2011, 2011). Correlates of sedentary time and physical activity among preschool-aged children. *Preventing Chronic Disease, 8*(6), A131-A131.

159. Donnelly, S., Buchan, D. S., McLellan, G., & Arthur, R. (2020, 2020). Relationship between parent and child physical activity using novel acceleration metrics. *Research quarterly for exercise and sport*.

160. Dooley, E. E., Pettee Gabriel, K., Kohl, H. W., 3rd, Durand, C. P., Hoelscher, D. M., & Byrd-Williams, C. E. (2020, 2020). Adiposity, cardiovascular, and health-related quality of life indicators and the reallocation of waking movement behaviors in preschool children with overweight and obesity: An isotemporal data analysis. *PLoS One, 15*(11), e0242088.

161. Dörr, C. S. B., Christina Fischer, Joachim E. De Bock, Freia. (2014, 2014). Preschools' friendliness toward physical activity: Item battery and two scores developed by mixed methods. *American Journal of Preventive Medicine, 46*(6), 593-604.

162. Dossegger, A. R., N. Jimmy, G. Braun-Fahrl er, C. Mader, U. Hanggi, J. Hofmann, H. Puder, J. J. Kriemler, S. Bringolf-Isler, B. (2014, 2014). Reactivity to accelerometer measurement of children and adolescents. *Medicine & Science in Sports & Exercise, 46*(6), 1140-1146. https://doi.org/10.1249/MSS.0000000000000215

163. Dowda, M. B., W. H. McIver, K. L. Pfeiffer, K. A. O'Neill, J. R. Addy, C. L. Pate, R. R. (2009, 2009). Policies and characteristics of the preschool environment and physical activity of young children. *Pediatrics, 123*(2), e261-266.

164. Dowda, M. P., K. A. Brown, W. H. Mitchell, J. A. Byun, W. Pate, R. R. (2011, 2011). Parental and environmental correlates of physical activity of children attending preschool. *Archives of Pediatrics & Adolescent Medicine, 165*(10), 939-944. https://doi.org/10.1001/archpediatrics.2011.84

165. Downing, K. L., Hinkley, T., Timperio, A., Salmon, J., Carver, A., Cliff, D. P., Okely, A. D., & Hesketh, K. D. (2021, 2021). Volume and accumulation patterns of physical activity and sedentary time: Longitudinal changes and tracking from early to late childhood. *The International Journal of Behavioral Nutrition and Physical Activity, 18*(1), 39.

166. Downing, K. L. H., T. Hesketh, K. D. (2015, 2015). Associations of parental rules and socioeconomic position with preschool children's sedentary behaviour and screen time. *Journal of Physical Activity & Health, 12*(4), 515-521. https://doi.org/10.1123/jpah.2013-0427

167. Downing, K. L. H., T. Salmon, J. Hnatiuk, J. A. Hesketh, K. D. (2017, 2017). Do the correlates of screen time and sedentary time differ in preschool children? *BMC Public Health, 17*(1), 285.

168. Draper, C., Tomaz, S. A., Cook, C. J., Jugdav, S. S., Ramsammy, C., Besharati, S., Heerden, A. v., Vilakazi, K., Cockcroft, K., Howard, S. J., & Okely, A. D. (2020, 2020). Understanding the influence of 24-hour movement behaviours on the health and development of preschool children from low-income south african settings: The sunrise pilot study. *South African Journal of Sports Medicine, 32*(12), 12-unpaginated.

169. Draper, C. E. T., S. A. Jones, R. A. Hinkley, T. Twine, R. Kahn, K. Norris, S. A. (2019, 2019). Cross-sectional associations of physical activity and gross motor proficiency with adiposity in south african children of pre-school age. *Public Health Nutrition, 22*(4), 614-623. https://doi.org/10.1017/S1368980018003579

170. Driediger, M., Truelove, S., Johnson, A. M., Vanderloo, L. M., Timmons, B. W., Burke, S. M., Irwin, J. D., & Tucker, P. (2019, 2019). The impact of shorter, more frequent outdoor play periods on preschoolers' physical activity during childcare: A cluster randomized controlled trial. *International journal of environmental research and public health, 16*(21).

171. Driessen, L. M. K.-d. J., J. C. Wijtzes, A. de Vries, S. I. Jaddoe, V. W. Hofman, A. Raat, H. Moll, H. A. (2013, 2013). Preschool physical activity and functional constipation: The generation r study. *Journal of Pediatric Gastroenterology & Nutrition, 57*(6), 768-774. https://doi.org/10.1097/MPG.0b013e3182a313fc

172. Driessen, L. M. K.-d. J., J. C. Jaddoe, V. W. Hofman, A. Raat, H. de Jongste, J. C. Moll, H. A. (2014, 2014). Physical activity and respiratory symptoms in children: The generation r study. *Pediatric Pulmonology, 49*(1), 36-42. https://doi.org/10.1002/ppul.22839

173. DuBose, K. D. G. M., A. Wood, A. P. Sisson, S. B. (2018, 2018). Joint relationship between physical activity, weight status, and motor skills in children aged 3 to 10 years. *Perceptual & Motor Skills, 125*(3), 478-492. https://doi.org/10.1177/0031512518767008

174. Duff, C., Issartel, J., O'Brien, W., & Belton, S. (2019, 2019). Kids active: Evaluation of an educator-led active play and fundamental movement skill intervention in the irish preschool setting. *Journal of Motor Learning and Development, 7*(3), 389-407.

175. Duff, C., Issartel, J., O'Brien, W., & Belton, S. (2019, 2019). Physical activity and fundamental movement skills of 3- to 5-year-old children in irish preschool services. *Journal of Motor Learning and Development, 7*(3), 354-373.

176. Duraccio, K. M. J., C. D. (2017, 2017). Associations between physical and sedentary activity regularity and sleep in preschoolers and kindergartners. *Sleep Health, 3*(4), 263-268.

177. Dwyer, G. M. H., L. L. Peat, J. K. Baur, L. A. (2011, 2011). The validity and reliability of a home environment preschool-age physical activity questionnaire (pre-paq). *International Journal of Behavioral Nutrition & Physical Activity, 8*, 86. https://doi.org/10.1186/1479-5868-8-86

178. Ebenegger, V. M.-V., P. Kriemler, S. Nydegger, A. Zahner, L. Niederer, I. Burgi, F. Puder, J. J. (2012, 2012). Differences in aerobic fitness and lifestyle characteristics in preschoolers according to their weight status and sports club participation. *Obesity Facts, 5*(1), 23-33.

179. Edwards, N. M. K., P. R. Kalkwarf, H. J. Claytor, R. P. Daniels, S. R. (2012, May). Is physical activity set in stone? Tracking of accelerometer-measured activity in early childhood. *Medicine and science in sports and exercise, 44*, 656-657. https://doi.org/10.1249/01.mss.0000417529.22755.ed

180. Edwards, N. M. K., Philip R. Kalkwarf, Heidi J. Woo, Jessica G. Claytor, R al P. Daniels, Stephen R. (2013, 2013). Tracking of accelerometer-measured physical activity in early childhood. *Pediatric Exercise Science, 25*(3), 487-501.

181. Edwards, N. M. M., G. D. Kalkwarf, H. J. Woo, J. G. Khoury, P. R. Hewett, T. E. Daniels, S. R. (2015, 2015). Outdoor temperature, precipitation, and wind speed affect physical activity levels in children: A longitudinal cohort study. *Journal of Physical Activity & Health, 12*(8), 1074-1081. https://doi.org/10.1123/jpah.2014-0125

182. Eichinger, M. S., S. De Bock, F. (2017, 2017). Subjectively and objectively assessed social and physical environmental correlates of preschoolers' accelerometer-based physical activity. *International Journal of Behavioral Nutrition & Physical Activity, 14*(1), 153. https://doi.org/10.1186/s12966-017-0577-9

183. Eichinger, M. S., S. De Bock, F. (2018, 2018). Subjectively and objectively assessed behavioral, social, and physical environmental correlates of sedentary behavior in preschoolers. *Journal of Pediatrics, 199*, 71-78.e73. https://doi.org/10.1016/j.jpeds.2018.04.011

184. Eijkemans, M., Mommers, M., Remmers, T., Draaisma, J. M. T., Prins, M. H., & Thijs, C. (2020, 2020). Physical activity and asthma development in childhood: Prospective birth cohort study. *Pediatric Pulmonology, 55*(1), 76-82.

185. Ekelund, U. L., J. Sherar, L. B. Esliger, D. W. Griew, P. Cooper, A. Ekelund, Ulf Luan, Jian'an Sherar, Lauren B. Esliger, Dale W. Griew, Pippa Cooper, Ashley. (2012, 2012). Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. *JAMA: Journal of the American Medical Association, 307*(7), 704-712.

186. El Nokali, N. E. (2013). *The intersection of physical activity, self-regulation and academic achievement: Implications for educational success* ProQuest Information & Learning]. US.

187. Er, V. D., K. I. Papadaki, A. White, J. Wells, S. Ward, D. S. Metcalfe, C. Jago, R. Kipping, R. (2018, 2018). Association of diet in nurseries and physical activity with zbmi in 2-4-year olds in england: A cross-sectional study. *BMC Public Health, 18*(1), 1262.

188. Erinosho, T. H., D. Vaughn, A. Mazzucca, S. Ward, D. S. (2016, 2016). Impact of policies on physical activity and screen time practices in 50 child-care centers in north carolina. *Journal of Physical Activity & Health, 13*(1), 59-66. https://doi.org/10.1123/jpah.2014-0467

189. España-Romero, V. M., Jonathan A. Dowda, Marsha O'Neill, Jennifer R. Pate, Russell R. (2013, 2013). Objectively measured sedentary time, physical activity and markers of body fat in preschool children. *Pediatric Exercise Science, 25*(1), 154-163.

190. Ettienne, R. N., C. R. Li, F. Su, Y. McGlone, K. Luick, B. Tachibana, A. Carran, C. Mercado, J. Novotny, R. (2016, 2016). Validation of the actical accelerometer in multiethnic preschoolers: The children's healthy living (chl) program. *Hawai'i Journal of Medicine & Public Health : A Journal of Asia Pacific Medicine & Public Health, 75*(4), 95-100.

191. Eythorsdottir, D. Y., Frederiksen, P., Larsen, S. C., Olsen, N. J., & Heitmann, B. L. (2020, 2020). Associations between objective measures of physical activity, sleep and stress levels among preschool children. *BMC Pediatrics, 20*(1), 1-7.

192. Fang, H. Q., M. Zhou, T. Sun, S. Zhang, J. Zhang, H. Cao, Z. Zhao, G. Wang, R. Chen, P. (2017, 2017). Relationship between physical activity and physical fitness in preschool children: A cross-sectional study. *BioMed Research International, 2017*, 9314026.

193. Felzer-Kim, I. T., & Hauck, J. L. (2020, 2020). Sleep duration associates with moderate-to-vigorous intensity physical activity and body fat in 1-to 3-year-old children. *Infant Behavior & Development, 58*.

194. Fisher, A. B., J. M. Paton, J. Y. Tomporowski, P. Watson, C. McColl, J. H. Reilly, J. J. (2011, 2011). Effects of a physical education intervention on cognitive function in young children: Randomized controlled pilot study. *BMC Pediatrics, 11*, 97.

195. Fitzgibbon, M. L. S., M. R. Schiffer, L. A. Braunschweig, C. L. Gomez, S. L. Van Horn, L. Dyer, A. R. (2011, May). Hip-hop to health jr. Obesity prevention effectiveness trial: Postintervention results. *Obesity, 19*(5), 994-1003.

196. Fossdal, T. S. K., K. egard, B. H. Lagestad, P. (2018, 2018). "Oh oobe doo, i wanna be like you" associations between physical activity of preschool staff and preschool children. *PLoS ONE [Electronic Resource], 13*(11), e0208001. https://doi.org/10.1371/journal.pone.0208001

197. Foweather, L. K., Zoe Ridgers, Nicola D. O’Dwyer, Mareesa V. Foulkes, Jonathan D. Stratton, Gareth O'Dwyer, Mareesa V. (2015, 2015). Fundamental movement skills in relation to weekday and weekend physical activity in preschool children. *Journal of Science & Medicine in Sport, 18*(6), 691-696. https://doi.org/10.1016/j.jsams.2014.09.014

198. Francis, S. L. L., E. M. Levy, S. M. Janz, K. F. (2014, 2014). Sustained effects of physical activity on bone health: Iowa bone development study. *Bone, 63*, 95-100.

199. Francis, S. L. M., Joanna L. Letuchy, Elena M. Levy, Steven M. Janz, Kathleen F. (2013, 2013). Ten-year objective physical activity tracking: Iowa bone development study. *Medicine & Science in Sports & Exercise, 45*(8), 1508-1514. https://doi.org/10.1249/MSS.0b013e31828b2f3a

200. Francis, S. L. S., M. J. Sernulka-George, F. D. Broffitt, B. Levy, S. M. Janz, K. F. (2011, 2011). Tracking of tv and video gaming during childhood: Iowa bone development study. *International Journal of Behavioral Nutrition & Physical Activity, 8*, 100. https://doi.org/10.1186/1479-5868-8-100

201. Frank, M. L. F., Anna Farnell, Gregory S. Barkley, Jacob E. (2018, 2018). The differences in physical activity levels in preschool children during free play recess and structured play recess. *Journal of Exercise Science & Fitness, 16*(1), 37-42. https://doi.org/10.1016/j.jesf.2018.03.001

202. French, S. A. S., N. E. Mitchell, N. R. Fan, Y. (2017, 2017). Park use is associated with less sedentary time among low-income parents and their preschool child: The net-works study. *Preventive Medicine Reports, 5*, 7-12.

203. Gabel, L. O., J. Nguyen, T. Proudfoot, N. A. Timmons, B. W. (2011, 2011). Short-term muscle power and speed in preschoolers exhibit stronger tracking than physical activity. *Applied Physiology, Nutrition, & Metabolism = Physiologie Appliquee, Nutrition et Metabolisme, 36*(6), 939-945. https://doi.org/10.1139/h11-118

204. Gabel, L. P., N. A. Obeid, J. MacDonald, M. J. Bray, S. R. Cairney, J. Timmons, B. W. (2013, 2013). Step count targets corresponding to new physical activity guidelines for the early years. *Medicine & Science in Sports & Exercise, 45*(2), 314-318. https://doi.org/10.1249/MSS.0b013e318271765a

205. Gagné, C. H., Isabelle. (2013, 2013). The contribution of psychosocial variables in explaining preschoolers' physical activity. *Health Psychology, 32*(6), 657-665. https://doi.org/10.1037/a0031638

206. Garriguet, D. (2016, 2016). Using a betabinomial distribution to estimate the prevalence of adherence to physical activity guidelines among children and youth. *Health Reports, 27*(4), 3-9.

207. Garriguet, D. C., V. Colley, R. C. Janssen, I. Timmons, B. W. Tremblay, M. S. (2016, 2016). Physical activity and sedentary behaviour of canadian children aged 3 to 5. *Health Reports, 27*(9), 14-23.

208. Goldfield, G. S. H., A. L. J. Grattan, K. P. Temple, V. Naylor, P. J. Alberga, A. S. Ferraro, Z. M. Wilson, S. Cameron, J. D. Barrowman, N. Adamo, K. B. (2016, 2016). Effects of child care intervention on physical activity and body composition. *American Journal of Preventive Medicine, 51*(2), 225-231.

209. Goldsmith, J. L., X. Jacobson, J. S. Rundle, A. (2016, 2016). New insights into activity patterns in children, found using functional data analyses. *Medicine & Science in Sports & Exercise, 48*(9), 1723-1729. https://doi.org/10.1249/MSS.0000000000000968

210. Goulding, A. T., R. W. Grant, A. M. Jones, S. Taylor, B. J. Williams, S. M. (2009, 2009). Relationships of appendicular lmi and total body lmi to bone mass and physical activity levels in a birth cohort of new zealand five-year olds. *Bone, 45*(3), 455-459.

211. Greever, C. J. S., J. Alhassan, S. (2015, 2015). Objective analysis of preschoolers' physical activity patterns during free playtime. *Journal of Physical Activity & Health, 12*(9), 1253-1258. https://doi.org/10.1123/jpah.2014-0307

212. Gronholt Olesen, L. L. K., P. Korsholm, L. Boye Koch, A. Froberg, K. (2015, 2015). Correlates of objectively measured physical activity in 5-6-year-old preschool children. *Journal of Sports Medicine & Physical Fitness, 55*(5), 513-526.

213. Grøntved, A. P., G. S. Andersen, L. B. Kristensen, P. L. Møller, N. C. Froberg, K. (2009, 2009). Personal characteristics and demographic factors associated with objectively measured physical activity in children attending preschool. *Pediatric Exercise Science, 21*(2), 209-219. https://doi.org/10.1123/pes.21.2.209

214. Grzywacz, J. G. S., Cynthia K. Zapata Roblyer, Martha I. Trejo, Grisel Arcury, Thomas A. Ip, Edward H. Wei, Lang Qu t, Sara A. (2014, 2014). Physical activity of preschool-aged latino children in farmworker families. *American Journal of Health Behavior, 38*(5), 717-725.

215. Guan, H., Zhang, Z., Wang, B., Okely, A. D., Tong, M., Wu, J., & Zhang, T. (2020, 2020). Proportion of kindergarten children meeting the who guidelines on physical activity, sedentary behaviour and sleep and associations with adiposity in urban beijing. *BMC Pediatrics, 20*(1), 1-9.

216. Gubbels, J. S. S., K. van de Kolk, I. de Vries, N. K. Thijs, C. Kremers, S. P. J. (2018, 2018). Energy balance-related parenting and child-care practices: The importance of meso-system consistency. *PLoS ONE [Electronic Resource], 13*(9), e0203689. https://doi.org/10.1371/journal.pone.0203689

217. Gubbels, J. S. V. K., D. H. H. Cardon, G. Kremers, S. P. J. (2018, 2018). Activating childcare environments for all children: The importance of children's individual needs. *International Journal of Environmental Research & Public Health [Electronic Resource], 15*(7), 03.

218. Gunter, K. B. R., K. R. Ward, D. S. Trost, S. G. (2012, 2012). Factors associated with physical activity in children attending family child care homes. *Preventive Medicine, 54*(2), 131-133.

219. Guo, H. S., Michaela A. O'Neill, Jennifer R. Dowda, Marsha Pate, Russell R. (2018, 2018). How does the relationship between motor skill performance and body mass index impact physical activity in preschool children? *Pediatric Exercise Science, 30*(2), 266-272. https://doi.org/10.1123/pes.2017-0074

220. Gutierrez-Hervas, A., Cortes-Castell, E., Juste-Ruiz, M., & Rizo-Baeza, M. (2020, 2020). Which variables influence compliance with physical activity recommendations in young children? *Anales De Pediatria, 92*(3), 156-164.

221. Gutierrez-Hervas, A. C.-C., E. Juste-Ruiz, M. Palazon-Bru, A. Gil-Guillen, V. Rizo-Baeza, M. M. (2018, 2018). Physical activity values in two- to seven-year-old children measured by accelerometer over five consecutive 24-hour days. *Nutricion Hospitalaria, 35*(3), 527-532. https://doi.org/10.20960/nh.1403

222. Gwozdz, W. S.-P., A. Reisch, L. A. Ahrens, W. Eiben, G. J, M. Fern ez-Alvira Hadjigeorgiou, C. De Henauw, S. Kovacs, E. Lauria, F. Veidebaum, T. Williams, G. Bammann, K. (2013, 2013). Maternal employment and childhood obesity--a european perspective. *Journal of Health Economics, 32*(4), 728-742.

223. Hager, E. R. C., C. J. Bentley, L. M. Hurley, K. M. Wang, Y. Black, M. M. (2016, 2016). Nighttime sleep duration and sleep behaviors among toddlers from low-income families: Associations with obesogenic behaviors and obesity and the role of parenting. *Childhood Obesity, 12*(5), 392-400.

224. Hager, E. R. G., C ice E. Latta, Laura W. Treuth, Margarita S. Caulfield, Laura E. Black, Maureen M. (2016, 2016). Toddler physical activity study: Laboratory and community studies to evaluate accelerometer validity and correlates. *BMC Public Health, 16*(1), 1-10. https://doi.org/10.1186/s12889-016-3569-9

225. Hager, E. R. T., N. A. Wang, Y. Kapur, N. C. Arbaiza, R. Merry, B. C. Black, M. M. (2017, 2017). The home environment and toddler physical activity: An ecological momentary assessment study. *Pediatric Obesity, 12*(1), 1-9.

226. Haines, J. D., Sabrina Mirotta, Julia A. O'Kane, Carley Breau, Rebecca Walton, Kathryn Krystia, Owen Chamoun, Elie Annis, Angela Darlington, Gerarda A. Buchholz, Andrea C. Duncan, Alison M. Vallis, Lori A. Spriet, Lawrence L. Mutch, David M. Brauer, Paula Allen-Vercoe, Emma Taveras, Elsie M. Ma, David W. L. on behalf of the Guelph Family Health, Study. (2018, 2018). Guelph family health study: Pilot study of a home-based obesity prevention intervention. *Canadian Journal of Public Health, 109*(4), 549-560. https://doi.org/10.17269/s41997-018-0072-3

227. Hall, C. J. S. E., E. L. J. Oxford, S. W. Duncan, M. J. (2019, 2019). Does perception of motor competence mediate associations between motor competence and physical activity in early years children? *Sports, 7*(4), 01. https://doi.org/10.3390/sports7040077

228. Hammersley, M. L., Okely, A. D., Batterham, M. J., & Jones, R. A. (2020, 2020). Can parental engagement in social media enhance outcomes of an online healthy lifestyle program for preschool-aged children? *Health Communication, 35*(9), 1162-1171.

229. Hammersley, M. L. O., A. D. Batterham, M. J. Jones, R. A. (2019, Feb). An internet-based childhood obesity prevention program (time2bhealthy) for parents of preschool-aged children: Randomized controlled trial. *Journal of Medical Internet Research, 21*(2), e11964. https://doi.org/10.2196/11964

230. Hansen, B. H. A., S. A. Andersen, L. B. Hildebr , M. Kolle, E. Steene-Johannessen, J. Kriemler, S. Page, A. S. Puder, J. J. Reilly, J. J. Sardinha, L. B. van Sluijs, E. M. F. Wedderkopp, N. Ekelund, U. International Children's Accelerometry Database, Collaborators. (2018, 2018). Cross-sectional associations of reallocating time between sedentary and active behaviours on cardiometabolic risk factors in young people: An international children's accelerometry database (icad) analysis. *Sports Medicine, 48*(10), 2401-2412.

231. Harrison, F. G., A. van Sluijs, E. M. F. Andersen, L. B. Cardon, G. Davey, R. Janz, K. F. Kriemler, S. Molloy, L. Page, A. S. Pate, R. Puder, J. J. Sardinha, L. B. Timperio, A. Wedderkopp, N. Jones, A. P. on behalf the, Icad collaborators. (2017, 2017). Weather and children's physical activity; how and why do relationships vary between countries? *International Journal of Behavioral Nutrition & Physical Activity, 14*(1), 74. https://doi.org/10.1186/s12966-017-0526-7

232. Hartman, E., Ketelaar, D., Lu, C. C., & Corpeleijn, E. (2019, 2019). Objectively measured physical activity and psychosocial functioning in young children: The gecko drenthe cohort. *Journal of Sports Sciences, 37*(19), 2198-2204.

233. Harvey, N. C. C., Z. A. Crozier, S. R. Kim, M. Ntani, G. Goodfellow, L. Robinson, S. M. Inskip, H. M. Godfrey, K. M. Dennison, E. M. Wareham, N. Ekelund, U. Cooper, C. Group, S. W. S. Study. (2012, 2012). Physical activity, calcium intake and childhood bone mineral: A population-based cross-sectional study. *Osteoporosis International, 23*(1), 121-130.

234. Hauck, J. L., & Felzer-Kim, I. T. (2019, 2019). Time spent in sedentary activity is related to gross motor ability during the second year of life. *Percept Mot Skills, 126*(5), 753-763.

235. He, Q., Ng, J. Y. Y., Cairney, J., Bedard, C., & Ha, A. S. C. (2021, 2021). Association between physical activity and fundamental movement skills in preschool-aged children: Does perceived movement skill competence mediate this relationship? *International journal of environmental research and public health, 18*(3).

236. Heale, L. D. B., C. M. Maguire, J. L. Parkin, P. C. Birken, C. S. (2014, May). Objectively measured physical activity of infants, toddlers, and preschool-aged children using accelerometry. *Journal of Physical Activity & Health, 11*, S152-S152. https://doi.org/10.1123/jpah.2014-0173

237. Hebestreit, A. B., Gianvincenzo De Henauw, Stefaan Eiben, Gabriele Hadjigeorgiou, Charalampos Kovács, Éva Krogh, Vittorio Moreno, Luis A. Pala, Valeria Veidebaum, Toomas Wolters, Maike Börnhorst, Claudia. (2016, 2016). Cross-sectional and longitudinal associations between energy intake and bmi z-score in european children. *International Journal of Behavioral Nutrition & Physical Activity, 13*, 1-11. https://doi.org/ARTN 23 10.1186/s12966-016-0344-3

238. Heerman, W. T., Julie Wallston, Kenneth Barkin, Shari. (2017, 2017). Parenting self-efficacy, parent depression, and healthy childhood behaviors in a low-income minority population: A cross-sectional analysis. *Maternal & Child Health Journal, 21*(5), 1156-1165. https://doi.org/10.1007/s10995-016-2214-7

239. Henderson, K. E. G., G. M. O'Connell, M. L. Schwartz, M. B. (2015, 2015). Environmental factors associated with physical activity in childcare centers. *International Journal of Behavioral Nutrition & Physical Activity, 12*, 43. https://doi.org/10.1186/s12966-015-0198-0

240. Henriksson, H. F., E. Lof, M. (2014, May). Evaluation of actiheart and a 7d activity diary for estimating free-living total and activity energy expenditure using criterion methods in 1 center dot 5- and 3-year-old children. *British Journal of Nutrition, 111*(10), 1830-1840.

241. Herbert, J., Matlosz, P., Lenik, J., Szybisty, A., Baran, J., Przednowek, K., & Wyszynska, J. (2020, 2020). Objectively assessed physical activity of preschool-aged children from urban areas. *International journal of environmental research and public health, 17*(4).

242. Herriott, S. K. (2013). *Evaluating interventions to increase physical activity in preschool children with and without disabilities* ProQuest Information & Learning]. US.

243. Herrmann, D. B., C. Sioen, I. Kouride, Y. Marild, S. Molnar, D. Mouratidou, T. Pitsiladis, Y. Russo, P. Veidebaum, T. Ahrens, W. consortium, Idefics. (2015, 2015). Impact of physical activity, sedentary behaviour and muscle strength on bone stiffness in 2-10-year-old children-cross-sectional results from the idefics study. *International Journal of Behavioral Nutrition & Physical Activity, 12*, 112. https://doi.org/10.1186/s12966-015-0273-6

244. Herrmann, D. P., H. Gianfagna, F. Konstabel, K. Lissner, L. Marild, S. Molnar, D. Moreno, L. A. Siani, A. Sioen, I. Veidebaum, T. Ahrens, W. Consortium, Idefics. (2015, 2015). Association between bone stiffness and nutritional biomarkers combined with weight-bearing exercise, physical activity, and sedentary time in preadolescent children. A case-control study. *Bone, 78*, 142-149.

245. Herzig, D. E., P. Radtke, T. Wenger, A. Rusterholz, T. Wilhelm, M. Achermann, P. Arhab, A. Jenni, O. G. Kakebeeke, T. H. Leeger-Aschmann, C. S. Messerli-Burgy, N. Meyer, A. H. Munsch, S. Puder, J. J. Schmutz, E. A. Stulb, K. Zysset, A. E. Kriemler, S. (2017, 2017). Relation of heart rate and its variability during sleep with age, physical activity, and body composition in young children. *Frontiers in Physiology, 8*, 109.

246. Hesketh, K. D., Salmon, J., McNaughton, S. A., Crawford, D., Abbott, G., Cameron, A. J., Lioret, S., Gold, L., Downing, K. L., & Campbell, K. J. (2020, 2020). Long-term outcomes (2 and 3.5 years post-intervention) of the infant early childhood intervention to improve health behaviors and reduce obesity: Cluster randomised controlled trial follow-up. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1).

247. Hesketh, K. D. C., K. Salmon, J. McNaughton, S. A. McCallum, Z. Cameron, A. Ball, K. Gold, L. Andrianopoulos, N. Crawford, D. (2013, 2013). The melbourne infant feeding, activity and nutrition trial (infant) program follow-up. *Contemporary Clinical Trials, 34*(1), 145-151.

248. Hesketh, K. R. B., S. Cooper, C. Godfrey, K. M. Harvey, N. C. Inskip, H. M. Robinson, S. M. Van Sluijs, E. M. F. (2019, 2019). The association between maternal-child physical activity levels at the transition to formal schooling: Cross-sectional and prospective data from the southampton women's survey. *International Journal of Behavioral Nutrition & Physical Activity, 16*(1), 23. https://doi.org/10.1186/s12966-019-0782-9

249. Hesketh, K. R. G., Laura Ekelund, Ulf McMinn, Alison M. Godfrey, Keith M. Inskip, Hazel M. Cooper, Cyrus Harvey, Nicholas C. van Sluijs, Esther M. F. (2014, 2014). Activity levels in mothers and their preschool children. *Pediatrics, 133*(4), e973-e980.

250. Hesketh, K. R. G., Simon J. van Sluijs, Esther M. F. (2015, 2015). Uk preschool-aged children's physical activity levels in childcare and at home: A cross-sectional exploration. *International Journal of Behavioral Nutrition & Physical Activity, 12*, 1-9. https://doi.org/ARTN 123 10.1186/s12966-015-0286-1

251. Hesketh, K. R. M., Alison M. Griffin, Simon J. Harvey, Nicholas C. Godfrey, Keith M. Inskip, Hazel M. Cooper, Cyrus van Sluijs, Esther Mf van Sluijs, Esther M. F. (2013, 2013). Maternal awareness of young children's physical activity: Levels and cross-sectional correlates of overestimation. *BMC Public Health, 13*(1), 924-924. https://doi.org/10.1186/1471-2458-13-924

252. Hesketh, K. R. M., A. M. Ekelund, U. Sharp, S. J. Collings, P. J. Harvey, N. C. Godfrey, K. M. Inskip, H. M. Cooper, C. van Sluijs, E. M. (2014, 2014). Objectively measured physical activity in four-year-old british children: A cross-sectional analysis of activity patterns segmented across the day. *International Journal of Behavioral Nutrition & Physical Activity, 11*, 1. https://doi.org/10.1186/1479-5868-11-1

253. Hesketh, K. R. v. S., E. M. (2016, 2016). Features of the uk childcare environment and associations with preschooler's in-care physical activity. *Preventive Medicine Reports, 3*, 53-57.

254. Hinkley, T. O. C., E. Okely, A. D. Crawford, D. Hesketh, K. Salmon, J. (2012, 2012). Assessing volume of accelerometry data for reliability in preschool children. *Medicine & Science in Sports & Exercise, 44*(12), 2436-2441. https://doi.org/10.1249/MSS.0b013e3182661478

255. Hinkley, T. S., J. Okely, A. D. Crawford, D. Hesketh, K. (2012, 2012). Preschoolers' physical activity, screen time, and compliance with recommendations. *Medicine & Science in Sports & Exercise, 44*(3), 458-465. https://doi.org/10.1249/MSS.0b013e318233763b

256. Hinkley, T. S., J. Okely, A. D. Hesketh, K. Crawford, D. (2012, 2012). Correlates of preschool children's physical activity. *American Journal of Preventive Medicine, 43*(2), 159-167.

257. Hinkley, T. S., Jo Crawford, David Okely, Anthony D. Hesketh, Kylie D. (2016, 2016). Preschool and childcare center characteristics associated with children's physical activity during care hours: An observational study. *International Journal of Behavioral Nutrition & Physical Activity, 13*(1), 1-9. https://doi.org/10.1186/s12966-016-0444-0

258. Hinkley, T. T., A. Salmon, J. Hesketh, K. (2017, 2017). Does preschool physical activity and electronic media use predict later social and emotional skills at 6 to 8 years? A cohort study. *Journal of Physical Activity & Health, 14*(4), 308-316. https://doi.org/10.1123/jpah.2015-0700

259. Hislop, J. L., J. Rush, R. Grainger, A. Bulley, C. Reilly, J. J. Mercer, T. (2014, 2014). An investigation into the minimum accelerometry wear time for reliable estimates of habitual physical activity and definition of a standard measurement day in pre-school children. *Physiological Measurement, 35*(11), 2213-2228.

260. Hnatiuk, J. A. D., Ellen Hesketh, Kylie D. Cardon, Greet. (2017, 2017). Maternal-child co-participation in physical activity-related behaviours: Prevalence and cross-sectional associations with mothers and children's objectively assessed physical activity levels. *BMC Public Health, 17*(1), 1-7. https://doi.org/10.1186/s12889-017-4418-1

261. Hnatiuk, J. A. H., K. R. van Sluijs, E. M. (2016, 2016). Correlates of home and neighbourhood-based physical activity in uk 3-4-year-old children. *European Journal of Public Health, 26*(6), 947-953.

262. Hnatiuk, J. A. L., Karen E. Ridgers, Nicola D. Salmon, Jo Hesketh, Kylie D. (2019, 2019). Changes in volume and bouts of physical activity and sedentary time across early childhood: A longitudinal study. *International Journal of Behavioral Nutrition & Physical Activity, 16*(1), N.PAG-N.PAG. https://doi.org/10.1186/s12966-019-0805-6

263. Hnatiuk, J. A. R., Nicola D. Salmon, Jo Hesketh, Kylie D. (2017, 2017). Maternal correlates of young children's physical activity across periods of the day. *Journal of Science & Medicine in Sport, 20*(2), 178-183. https://doi.org/10.1016/j.jsams.2016.06.014

264. Hnatiuk, J. R., N. D. Salmon, J. Campbell, K. McCallum, Z. Hesketh, K. (2012, 2012). Physical activity levels and patterns of 19-month-old children. *Medicine & Science in Sports & Exercise, 44*(9), 1715-1720. https://doi.org/10.1249/MSS.0b013e31825825c4

265. Hnatiuk, J. S., J. Campbell, K. J. Ridgers, N. D. Hesketh, K. D. (2013, 2013). Early childhood predictors of toddlers' physical activity: Longitudinal findings from the melbourne infant program. *International Journal of Behavioral Nutrition & Physical Activity, 10*, 123. https://doi.org/10.1186/1479-5868-10-123

266. Hoffman, J. A., Schmidt, E. M., Arguello, D. J., Eyllon, M. N., Castaneda-Sceppa, C., Cloutier, G., & Hillman, C. H. (2020, 2020). Online preschool teacher training to promote physical activity in young children: A pilot cluster randomized controlled trial. *School Psychology, 35*(2), 118-127.

267. Howie, E. K. B., W. H. Dowda, M. McIver, K. L. Pate, R. R. (2013, 2013). Physical activity behaviours of highly active preschoolers. *Pediatric Obesity, 8*(2), 142-149.

268. Huang, C. C., Marja Crawford, Susan Dewey, Deborah Pacaud, Danièle. (2016, 2016). The relationship between physical activity level and cardiovascular disease biomarkers in healthy, normal-weight 3- to 6-year-old children and their parents. *Applied Physiology, Nutrition & Metabolism, 41*(8), 907-910. https://doi.org/10.1139/apnm-2016-0023

269. Hunter, S., Rosu, A., Hesketh, K. D., Rhodes, R. E., Rinaldi, C. M., Rodgers, W., Spence, J. C., & Carson, V. (2019, 2019). Objectively measured environmental correlates of toddlers' physical activity and sedentary behavior. *Pediatric Exercise Science, 31*(4), 480-487.

270. Iguacel, I. F.-A., Juan M. Bammann, Karin Chadjigeorgiou, Charalambos De Henauw, Stefaan Heidinger-Felső, Regina Lissner, Lauren Michels, Nathalie Page, Angie Reisch, Lucia A. Russo, Paola Sprengeler, Ole Veidebaum, Toomas Börnhorst, Claudia Moreno, Luis A. On behalf of the, Idefics consortium consortium, Idefics. (2018, 2018). Social vulnerability as a predictor of physical activity and screen time in european children. *International Journal of Public Health, 63*(2), 283-295.

271. Iivonen, K. S. S., A. K. Mehtala, A. Villberg, J. J. Tammelin, T. H. Kulmala, J. S. Poskiparta, M. (2013, 2013). Relationship between fundamental motor skills and physical activity in 4-year-old preschool children. *Perceptual & Motor Skills, 117*(2), 627-646. https://doi.org/10.2466/10.06.PMS.117x22z7

272. Ip, E. H. S., S. Trejo, G. Marshall, S. A. Suerken, C. K. Lang, W. Arcury, T. A. Qu t, S. A. (2016, 2016). Physical activity states of preschool-aged latino children in farmworker families: Predictive factors and relationship with bmi percentile. *Journal of Physical Activity & Health, 13*(7), 726-732. https://doi.org/10.1123/jpah.2015-0534

273. Irwin, J. D. J., A. M. erloo, L. M. Burke, S. M. Tucker, P. (2015, 2015). Temperament and objectively measured physical activity and sedentary time among canadian preschoolers. *Preventive Medicine Reports, 2*, 598-601.

274. Ishii, K. S., A. Adachi, M. Nonoue, K. Oka, K. (2015, 2015). Gender and grade differences in objectively measured physical activity and sedentary behavior patterns among japanese children and adolescents: A cross-sectional study. *BMC Public Health, 15*, 1254.

275. Jackson, D. M. D., K. Stewart, J. Speakman, J. R. (2009, 2009). Increased television viewing is associated with elevated body fatness but not with lower total energy expenditure in children. *American Journal of Clinical Nutrition, 89*(4), 1031-1036.

276. Jago, R. S., Simon J. Wood, Lesley Pool, Laura Zahra, Jesmond Thompson, Janice L. Lawlor, Deborah A. (2014, 2014). Associations between objectively assessed child and parental physical activity: A cross-sectional study of families with 5-6 year old children. *BMC Public Health, 14*(1), 655-655. https://doi.org/Artn 655 10.1186/1471-2458-14-655

277. Jago, R. S.-M., Emma Macdonald-Wallis, Corrie Thompson, Janice L. Lawlor, Deborah A. Sebire, Simon J. (2017, 2017). Association of parents' and children's physical activity and sedentary time in year 4 (8-9) and change between year 1 (5-6) and year 4: A longitudinal study. *International Journal of Behavioral Nutrition & Physical Activity, 14*(1), 1-10. https://doi.org/ARTN 110 10.1186/s12966-017-0565-0

278. Jago, R. S.-M., Emma Toumpakari, Zoi Lawlor, Deborah A. Thompson, Janice L. Sebire, Simon J. (2018, 2018). Parents' perspectives of change in child physical activity & screen-viewing between y1 (5-6) & y4 (8-9) of primary school: Implications for behaviour change. *BMC Public Health, 18*(1), N.PAG-N.PAG. https://doi.org/ARTN 520 10.1186/s12889-018-5445-2

279. Janz, K. F. L., E. M. Eichenberger Gilmore, J. M. Burns, T. L. Torner, J. C. Willing, M. C. Levy, S. M. (2010, 2010). Early physical activity provides sustained bone health benefits later in childhood. *Medicine & Science in Sports & Exercise, 42*(6), 1072-1078. https://doi.org/10.1249/MSS.0b013e3181c619b2

280. Janz, K. F. L., E. M. Burns, T. L. Eichenberger Gilmore, J. M. Torner, J. C. Levy, S. M. (2014, 2014). Objectively measured physical activity trajectories predict adolescent bone strength: Iowa bone development study. *British Journal of Sports Medicine, 48*(13), 1032-1036.

281. Janz, K. F. L., E. M. Francis, S. L. Metcalf, K. M. Burns, T. L. Levy, S. M. (2014, 2014). Objectively measured physical activity predicts hip and spine bone mineral content in children and adolescents ages 5-15 years: Iowa bone development study. *Frontiers in Endocrinology, 5*, 112.

282. Jauregui, A., Salvo, D., Garcia-Olvera, A., Villa, U., Tellez-Rojo, M. M., Schnaas, L. M., Svensson, K., Oken, E., Wright, R. O., Baccarelli, A. A., & Cantoral, A. (2020, 2020). Physical activity, sedentary time and cardiometabolic health indicators among mexican children. *Clinical Obesity, 10*(1), e12346.

283. Jauregui, A. V. o., S. Rangel-Baltazar, E. Castro-Hern ez, J. Lara-Zamudio, Y. Mendez-Gomez-Humaran, I. (2011, 2011). The physical activity level of mexican children decreases upon entry to elementary school. *Salud Publica de Mexico, 53*(3), 228-236.

284. Jensen, C. D. H., Sanita L. Van Dyk, Tori R. Nelson, Timothy D. ridge, Michael L. Bailey, Bruce W. (2015, 2015). Effectiveness of a parent health report intervention to increase physical activity among preschoolers and kindergarteners. *Children's Health Care, 44*(4), 341-352. https://doi.org/10.1080/02739615.2014.948162

285. Jia, Z. Z., Joni Trindade, Dulce Sobko, Tanja. (2018, 2018). Physical activity patterns and correlates of 9-month-old chinese infants in the macau population. *Maternal & Child Health Journal, 22*(10), 1526-1533. https://doi.org/10.1007/s10995-018-2614-y

286. Jimenez-Pavon, D. K., K. Bergman, P. Ahrens, W. Pohlabeln, H. Hadjigeorgiou, C. Siani, A. Iacoviello, L. Molnar, D. De Henauw, S. Pitsiladis, Y. Moreno, L. A. Consortium, Idefics. (2013, Jul). Physical activity and clustered cardiovascular disease risk factors in young children: A cross-sectional study (the idefics study). *BMC Medicine, 11*, 172. https://doi.org/10.1186/1741-7015-11-172

287. Johansson, E. H., M. Svensson, V. Ek, A. Forssen, M. Nero, H. Marcus, C. (2015, 2015). Objectively measured physical activity in two-year-old children - levels, patterns and correlates. *International Journal of Behavioral Nutrition & Physical Activity, 12*, 3. https://doi.org/10.1186/s12966-015-0161-0

288. Johansson, E. M., H. Xiu, L. Svensson, V. Xiong, Y. Marcus, C. Zhang, J. Hagstromer, M. (2016, 2016). Physical activity in young children and their parents-an early stopp sweden-china comparison study. *Scientific Reports, 6*, 29595.

289. Jones, R. A. O., A. D. Hinkley, T. Batterham, M. Burke, C. (2016, 2016). Promoting gross motor skills and physical activity in childcare: A translational randomized controlled trial. *Journal of Science & Medicine in Sport, 19*(9), 744-749. https://doi.org/10.1016/j.jsams.2015.10.006

290. Jones, R. A. R., Annaleise Hesketh, Kylie Trezise, Jillian Batterham, Marijka Okely, Anthony D. (2011, 2011). Promoting fundamental movement skill development and physical activity in early childhood settings: A cluster randomized controlled trial. *Pediatric Exercise Science, 23*(4), 600-615. https://doi.org/10.1123/pes.23.4.600

291. Kahan, D. N., V. Reuben, K. (2016, Fal). Effects of a bug-in-the-ear intervention to increase physical activity prompting and level during preschool recess. *Physical Educator-Us, 73*(3), 555-577. https://doi.org/10.18666/TPE-2016-V73-I3-6415

292. Kain, J. L., B. Concha, F. Close, M. Soto-Sanchez, J. Salazar, G. (2017, 2017). Preschool children's physical activity intensity during school time: Influence of school schedule. *Preventive Medicine Reports, 8*, 6-9.

293. Kain, J. L., B. Soto-Sanchez, J. Concha, F. (2018, 2018). In preschool children, physical activity during school time can significantly increase by intensifying locomotor activities during physical education classes. *BMC Research Notes, 11*(1), 438.

294. Kakebeeke, T. H. L., S. Zysset, A. E. Arhab, A. Messerli-Burgy, N. Stuelb, K. Leeger-Aschmann, C. S. Schmutz, E. A. Meyer, A. H. Kriemler, S. Munsch, S. Jenni, O. G. Puder, J. J. (2017, 2017). Association between body composition and motor performance in preschool children. *Obesity Facts, 10*(5), 420-431.

295. Karl, K. F. C., Karen A. (2014). *A behavioral intervention for child obesity: Increasing physical activity on the playground via reinforcement in a preschool classroom* (Publication Number 3639432) The University of Mississippi]. Ann Arbor.

296. Kawahara, J. T., S. Tanaka, C. Aoki, Y. Yonemoto, J. (2011, 2011). Estimation of daily inhalation rate in preschool children using a tri-axial accelerometer: A pilot study. *Science of the Total Environment, 409*(16), 3073-3077.

297. Kawahara, J. T., S. Tanaka, C. Aoki, Y. Yonemoto, J. (2012, 2012). Daily inhalation rate and time-activity/location pattern in japanese preschool children. *Risk Analysis, 32*(9), 1595-1604. https://doi.org/10.1111/j.1539-6924.2011.01776.x

298. Kesten, J. M. J., Russ Sebire, Simon J. Edwards, Mark J. Pool, Laura Zahra, Jesmond Thompson, Janice L. (2015, 2015). Understanding the accuracy of parental perceptions of child physical activity: A mixed methods analysis. *Journal of Physical Activity & Health, 12*(12), 1529-1535. https://doi.org/10.1123/jpah.2014-0442

299. Ketcheson, L. P., E. A. Kwon, H. J. Ulrich, D. A. (2017, 2017). Physical activity patterns in infants with and without down syndrome. *Pediatric Physical Therapy, 29*(3), 200-206. https://doi.org/10.1097/PEP.0000000000000397

300. Keyes, B. L., & Wilson, K. S. (2020, 2020). Influence of parental physical activity and sedentary behavior on young children: Considering time together. *Research quarterly for exercise and sport*.

301. Khalsa, A. S. K., R. Ollberding, N. J. Bishop, L. Copel , K. A. (2017, 2017). Attainment of '5-2-1-0' obesity recommendations in preschool-aged children. *Preventive Medicine Reports, 8*, 79-87.

302. Kim, H., Ma, J., Harada, K., Lee, S., & Gu, Y. (2020, 2020). Associations between adherence to combinations of 24-h movement guidelines and overweight and obesity in japanese preschool children. *International journal of environmental research and public health, 17*(24).

303. King-Dowling, S., Kwan, M. Y. W., Rodriguez, C., Missiuna, C., Timmons, B. W., & Cairney, J. (2019, 2019). Physical activity in young children at risk for developmental coordination disorder. *Developmental Medicine and Child Neurology, 61*(11), 1302-+.

304. King-Dowling, S., Proudfoot, N. A., Cairney, J., & Timmons, B. W. (2020, 2020). Motor competence, physical activity, and fitness across early childhood. *Medicine & Science in Sports & Exercise, 52*(11), 2342-2348.

305. King-Dowling, S. P., N. A. Di Cristofaro, N. Caldwell, H. A. T. Cairney, J. Timmons, B. W. (2016, 2016). Longitudinal relationship between motor proficiency, short-term muscle power and physical activity in the early years...2016 north american society for pediatric exercise medicine (naspem) biennial meeting, knoxville, tennessee. *Pediatric Exercise Science, 28*, 20-20. https://doi.org/10.1123/pes.2016.0242

306. King-Dowling, S. R., C. Missiuna, C. Timmons, B. W. Cairney, J. (2018, 2018). Health-related fitness in preschool children with and without motor delays. *Medicine & Science in Sports & Exercise, 50*(7), 1442-1448. https://doi.org/10.1249/MSS.0000000000001590

307. Kippe, K. O. L., P. A. (2018, 2018). Kindergarten: Producer or reducer of inequality regarding physical activity levels of preschool children. *Frontiers in Public Health, 6*, 361.

308. Konstabel, K. V., T. Verbestel, V. Moreno, L. A. Bammann, K. Tornaritis, M. Eiben, G. Molnar, D. Siani, A. Sprengeler, O. Wirsik, N. Ahrens, W. Pitsiladis, Y. consortium, Idefics. (2014, 2014). Objectively measured physical activity in european children: The idefics study. *International Journal of Obesity, 38*, S135-143.

309. Kracht, C. L., Webster, E. K., & Staiano, A. E. (2019, 2019). Sociodemographic differences in young children meeting 24-hour movement guidelines. *Journal of Physical Activity & Health, 16*(10), 908-915.

310. Kracht, C. L., Webster, E. K., & Staiano, A. E. (2020, 2020). A natural experiment of state-level physical activity and screen-time policy changes early childhood education (ece) centers and child physical activity. *BMC Public Health, 20*(1), 387-387.

311. Kuhl, E. S. C., L. M. stra, N. F. Filigno, S. S. Yeomans-Maldonado, G. Rausch, J. R. Stark, L. J. (2014, 2014). Examination of the association between lifestyle behavior changes and weight outcomes in preschoolers receiving treatment for obesity. *Health Psychology, 33*(1), 95-98.

312. Kuzik, N., Naylor, P. J., Spence, J. C., & Carson, V. (2020, 2020). Movement behaviours and physical, cognitive, and social-emotional development in preschool-aged children: Cross-sectional associations using compositional analyses. *PLoS One, 15*(8).

313. Kuzik, N. C., D. Ogden, N. Harber, V. Carson, V. (2015, 2015). Physical activity and sedentary behaviour of toddlers and preschoolers in child care centres in alberta, canada. *Canadian Journal of Public Health. Revue Canadienne de Sante Publique, 106*(4), e178-183. https://doi.org/10.17269/cjph.106.4794

314. Kuzik, N. C., V. (2016, 2016). The association between physical activity, sedentary behavior, sleep, and body mass index z-scores in different settings among toddlers and preschoolers. *BMC Pediatrics, 16*, 100.

315. Kwon, S., Honegger, K., & Mason, M. (2019, 2019). Daily physical activity among toddlers: Hip and wrist accelerometer assessments. *International journal of environmental research and public health, 16*(21).

316. Kwon, S. B., T. L. Levy, S. M. Janz, K. F. (2012, 2012). Breaks in sedentary time during childhood and adolescence: Iowa bone development study. *Medicine & Science in Sports & Exercise, 44*(6), 1075-1080. https://doi.org/10.1249/MSS.0b013e318245ca20

317. Kwon, S. J., K. F. Letuchy, E. M. Burns, T. L. Levy, S. M. (2015, 2015). Active lifestyle in childhood and adolescence prevents obesity development in young adulthood. *Obesity, 23*(12), 2462-2469.

318. Kwon, S. M., M. Becker, A. B. (2015, Jul). Environmental factors associated with child physical activity at childcare. *Health Behavior and Policy Review, 2*(4), 260-267. https://doi.org/10.14485/HBPR.2.4.3

319. Lahuerta-Contell, S., Molina-Garcia, J., Queralt, A., & Martinez-Bello, V. E. (2021, 2021). The role of preschool hours in achieving physical activity recommendations for preschoolers. *Children-Basel, 8*(2).

320. Larouche, R. G., D. Tremblay, M. S. (2017, 2017). Outdoor time, physical activity and sedentary time among young children: The 2012-2013 canadian health measures survey. *Canadian Journal of Public Health. Revue Canadienne de Sante Publique, 107*(6), e500-e506. https://doi.org/10.17269/cjph.107.5700

321. LaRowe, T. L. A., Alex ra K Jobe, Jared B Cronin, Kate A Vannatter, Suanne M Prince, Ronald J. (2010, 2010). Dietary intakes and physical activity among preschool-aged children living in rural american indian communities before a family-based healthy lifestyle intervention. *Journal of the American Dietetic Association, 110*(7), 1049-1057.

322. LaRowe, T. L. T., E. J. Meinen, A. M. Hoiting, J. Saxler, C. Cullen, B. Wisconsin Early Childhood Obesity Prevention, Initiative. (2016, 2016). Active early: One-year policy intervention to increase physical activity among early care and education programs in wisconsin. *BMC Public Health, 16*, 607.

323. Laukkanen, A. P., A. J. Heikkinen, R. Saakslahti, A. K. Finni, T. (2015, 2015). Family-based cluster randomized controlled trial enhancing physical activity and motor competence in 4-7-year-old children. *PLoS ONE [Electronic Resource], 10*(10), e0141124. https://doi.org/10.1371/journal.pone.0141124

324. Laukkanen, A. P., Arto J. Finni, Taija Sääkslahti, Arja. (2017, 2017). Parental support and objectively measured physical activity in children: A yearlong cluster-randomized controlled efficacy trial. *Research Quarterly for Exercise & Sport, 88*(3), 293-306. https://doi.org/10.1080/02701367.2017.1329924

325. Lebacq, T. O., C. Bel, S. Brocatus, L. Teppers, E. Cuypers, K. Tafforeau, J. De Ridder, K. A. (2016, 2016). Physical activity and sedentary behavior in belgium (bnfcs2014): Design, methods and expected outcomes. *Archives of Public Health, 74*, 44.

326. Lee, E. Y. H., K. D. Hunter, S. Kuzik, N. Rhodes, R. E. Rinaldi, C. M. Spence, J. C. Carson, V. (2017, 2017). Meeting new canadian 24-hour movement guidelines for the early years and associations with adiposity among toddlers living in edmonton, canada. *BMC Public Health, 17*, 840.

327. Lee, E. Y. H., K. D. Rhodes, R. E. Rinaldi, C. M. Spence, J. C. Carson, V. (2018, 2018). Role of parental and environmental characteristics in toddlers' physical activity and screen time: Bayesian analysis of structural equation models. *International Journal of Behavioral Nutrition & Physical Activity, 15*(1), 17. https://doi.org/10.1186/s12966-018-0649-5

328. Leech, R. M. M., S. A. Timperio, A. (2014, 2014). Clustering of children's obesity-related behaviours: Associations with sociodemographic indicators. *European Journal of Clinical Nutrition, 68*(5), 623-628.

329. Leech, R. M. M., S. A. Timperio, A. (2015, 2015). Clustering of diet, physical activity and sedentary behaviour among australian children: Cross-sectional and longitudinal associations with overweight and obesity. *International Journal of Obesity, 39*(7), 1079-1085.

330. Leeger-Aschmann, C. S. S., E. A. Radtke, T. Kakebeeke, T. H. Zysset, A. E. Messerli-Burgy, N. Stulb, K. Arhab, A. Meyer, A. H. Munsch, S. Jenni, O. G. Puder, J. J. Kriemler, S. (2016, 2016). Regional sociocultural differences as important correlate of physical activity and sedentary behaviour in swiss preschool children. *Swiss Medical Weekly, 146*, w14377.

331. Leeger-Aschmann, C. S. S., E. A. Zysset, A. E. Kakebeeke, T. H. Messerli-Burgy, N. Stulb, K. Arhab, A. Meyer, A. H. Munsch, S. Jenni, O. G. Puder, J. J. Kriemler, S. (2019, 2019). Accelerometer-derived physical activity estimation in preschoolers - comparison of cut-point sets incorporating the vector magnitude vs the vertical axis. *BMC Public Health, 19*(1), 513.

332. Lehto, E., Lehto, R., Ray, C., Pajulahti, R., Sajaniemi, N., Erkkola, M., & Roos, E. (2021, 2021). Are associations between home environment and preschool children's sedentary time influenced by parental educational level in a cross-sectional survey? *International Journal for Equity in Health, 20*(1).

333. Lehto, E. R., C. Vepsalainen, H. Korkalo, L. Lehto, R. Kaukonen, R. Suhonen, E. Nislin, M. Nissinen, K. Skaffari, E. Koivusilta, L. Sajaniemi, N. Erkkola, M. Roos, E. (2018, 2018). Increased health and wellbeing in preschools (dagis) study-differences in children's energy balance-related behaviors (ebrbs) and in long-term stress by parental educational level. *International Journal of Environmental Research & Public Health [Electronic Resource], 15*(10), 21.

334. Leis, A., Ward, S., Vatanparast, H., Humbert, M. L., Chow, A. F., Muhajarine, N., Engler-Stringer, R., & Belanger, M. (2020, 2020). Effectiveness of the healthy start-depart sante approach on physical activity, healthy eating and fundamental movement skills of preschoolers attending childcare centres: A randomized controlled trial. *BMC Public Health, 20*(1).

335. Leppanen, M. H., Kaseva, K., Pajulahti, R., Saaksjarvi, K., Makynen, E., Engberg, E., Ray, C., Erkkola, M., Sajaniemi, N., & Roos, E. (2021, 2021). Temperament, physical activity and sedentary time in preschoolers - the dagis study. *BMC Pediatrics, 21*(1), 129.

336. Leppanen, M. H., Ray, C., Wennman, H., Alexandrou, C., Saaksjarvi, K., Koivusilta, L., Erkkola, M., & Roos, E. (2019, 2019). Compliance with the 24-h movement guidelines and the relationship with anthropometry in finnish preschoolers: The dagis study. *BMC Public Health, 19*(1).

337. Leppänen, M. H. H., Pontus Delisle Nyström, Christine Henriksson, Hanna Ortega, Francisco B. Pomeroy, Jeremy Ruiz, Jonatan R. Cadenas-Sanchez, Cristina Löf, Marie. (2017, 2017). Longitudinal physical activity, body composition, and physical fitness in preschoolers. *Medicine & Science in Sports & Exercise, 49*(10), 2078-2085. https://doi.org/10.1249/Mss.0000000000001313

338. Leppanen, M. H. N., C. D. Henriksson, P. Pomeroy, J. Ruiz, J. R. Ortega, F. B. Cadenas-Sanchez, C. Lof, M. (2016, 2016). Physical activity intensity, sedentary behavior, body composition and physical fitness in 4-year-old children: Results from the ministop trial. *International Journal of Obesity, 40*(7), 1126-1133.

339. Li, S., Howard, J. T., Sosa, E. T., Cordova, A., Parra-Medina, D., & Yin, Z. (2020, 2020). Calibrating wrist-worn accelerometers for physical activity assessment in preschoolers: Machine learning approaches. *JMIR formative research, 4*(8), e16727.

340. Li, Y.-C., Kwan, M. Y. W., King-Dowling, S., Rodriguez, M. C., & Cairney, J. (2021, 2021). Does physical activity and bmi mediate the association between dcd and internalizing problems in early childhood? A partial test of the environmental stress hypothesis. *Human Movement Science, 75*, N.PAG-N.PAG.

341. Loprinzi, P. D. T., S. G. (2010, 2010). Parental influences on physical activity behavior in preschool children. *Preventive Medicine, 50*(3), 129-133.

342. Lovasi, G. S. J., J. S. Quinn, J. W. Neckerman, K. M. Ashby-Thompson, M. N. Rundle, A. Lovasi, Gina S. Jacobson, Judith S. Quinn, James W. Neckerman, Kathryn M. Ashby-Thompson, Maxine N. Rundle, Andrew. (2011, 2011). Is the environment near home and school associated with physical activity and adiposity of urban preschool children? *Journal of Urban Health, 88*(6), 1143-1157.

343. Lu, C. H., G. Corpeleijn, E. (2019, 2019). Environmental correlates of sedentary time and physical activity in preschool children living in a relatively rural setting in the netherlands: A cross-sectional analysis of the gecko drenthe cohort. *BMJ Open, 9*(5), e027468.

344. Ludwig, K. R., W. A. (2018, Oct). Associations between physical activity, positive affect, and self-regulation during preschoolers' everyday lives. *Mental Health and Physical Activity, 15*, 63-70. https://doi.org/10.1016/j.mhpa.2018.07.002

345. Määttä, S., Konttinen, H., de Oliveira Figueiredo, R. A., Haukkala, A., Sajaniemi, N., Erkkola, M., & Roos, E. (2020, 2020). Individual-, home- and preschool-level correlates of preschool children's sedentary time. *BMC Pediatrics, 20*(1), 1-14.

346. Maatta, S., Lehto, R., Konttinen, H., Ray, C., Sajaniemi, N., Erkkola, M., & Roos, E. (2019, 2019). Preschool group practices and preschool children's sedentary time: A cross-sectional study in finland. *BMJ Open, 9*(12), e032210.

347. Määttä, S. G., Jessica Ray, Carola Koivusilta, Leena Nislin, Mari Sajaniemi, Nina Erkkola, Maijaliisa Roos, Eva. (2019, 2019). Children’s physical activity and the preschool physical environment: The moderating role of gender. *Early Childhood Research Quarterly, 47*, 39-48. https://doi.org/10.1016/j.ecresq.2018.10.008

348. Maatta, S. K., H. Haukkala, A. Erkkola, M. Roos, E. (2017, 2017). Preschool children's context-specific sedentary behaviours and parental socioeconomic status in finland: A cross-sectional study. *BMJ Open, 7*(11), e016690.

349. Maatta, S. K., H. Lehto, R. Haukkala, A. Erkkola, M. Roos, E. (2018, 2018). Preschool environmental factors, parental socioeconomic status, and children's sedentary time: An examination of cross-level interactions. *International Journal of Environmental Research & Public Health [Electronic Resource], 16*(1), 25.

350. Maatta, S. R., C. Vepsalainen, H. Lehto, E. Kaukonen, R. Ylonen, A. Roos, E. (2018, 2018). Parental education and pre-school children's objectively measured sedentary time: The role of co-participation in physical activity. *International Journal of Environmental Research & Public Health [Electronic Resource], 15*(2), 20.

351. Maltby, A. M. e., Leigh M. Tucker, Patricia. (2018, 2018). Exploring mothers’ influence on preschoolers’ physical activity and sedentary time: A cross sectional study. *Maternal & Child Health Journal, 22*(7), 978-985. https://doi.org/10.1007/s10995-018-2474-5

352. Manco, L., Pinho, S., Albuquerque, D., Machado-Rodrigues, A. M., & Padez, C. (2019, 2019). Physical activity and the association between the fto rs9939609 polymorphism and obesity in portuguese children aged 3 to 11 years. *American Journal of Human Biology, 31*(6).

353. Martin, A. M., Mhairi Penpraze, Victoria Dall, Philippa Granat, Malcolm Paton, James Y. Reilly, John J. (2011, 2011). Objective measurement of habitual sedentary behavior in pre-school children: Comparison of activpal with actigraph monitors. *Pediatric Exercise Science, 23*(4), 468-476. https://doi.org/10.1123/pes.23.4.468

354. Martinez-Gomez, D. E., J. C. Tucker, J. Heelan, K. A. Welk, G. J. (2011, 2011). Associations between moderate-to-vigorous physical activity and central body fat in 3-8-year-old children. *International Journal of Pediatric Obesity, 6*(2), e611-614. https://doi.org/10.3109/17477166.2010.533775

355. Martinez-Gomez, D. T., J. Heelan, K. A. Welk, G. J. Eisenmann, J. C. (2009, 2009). Associations between sedentary behavior and blood pressure in young children. *Archives of Pediatrics & Adolescent Medicine, 163*(8), 724-730. https://doi.org/10.1001/archpediatrics.2009.90

356. Martins, C., Bandeira, P. F. R., Souza, A., Bezerra, T., Clark, C., Webster, E. K., Mota, J., & Duncan, M. (2021, 2021). The combination of three movement behaviours is associated with object control skills, but not locomotor skills, in preschoolers. *European Journal of Pediatrics*.

357. Martins, C. M. D., Lemos, L., de Souza, A. N., Bezerra, T. A., Soares, I. A. A., Mota, J. G., Bandeira, P. F. R., Mota, J., Tassitano, R. M., & Duncan, M. J. (2020, 2020). Adherence to 24-hour movement guidelines in low-income brazilian preschoolers and associations with demographic correlates. *American Journal of Human Biology*.

358. Matarma, T. L., Hanna Hurme, Saija Tammelin, Tuija H. Kulmala, Janne Barnett, Lisa M. Koski, Pasi. (2018, 2018). Motor skills in association with physical activity, sedentary time, body fat, and day care attendance in 5-6-year-old children—the steps study. *Scandinavian Journal of Medicine & Science in Sports, 28*(12), 2668-2676. https://doi.org/10.1111/sms.13264

359. Matarma, T. T., T. Kulmala, J. Koski, P. Hurme, S. Lagstrom, H. (2017, 2017). Factors associated with objectively measured physical activity and sedentary time of 5-6-year-old children in the steps study. *Early Child Development and Care, 187*(12), 1863-1873. https://doi.org/10.1080/03004430.2016.1193016

360. Mazzucca, S. H., D. Evenson, K. R. Ammerman, A. Tate, D. F. Berry, D. C. Ward, D. S. (2018, 2018). Physical activity opportunities within the schedule of early care and education centers. *Journal of Physical Activity & Health, 15*(2), 73-81. https://doi.org/10.1123/jpah.2017-0071

361. Mazzucca, S. L. (2018). *Physical activity and sedentary behavior in early care and education centers: Identifying opportunities and testing strategies to support active classroom environments* ProQuest Information & Learning]. US.

362. Mazzucca, S. N., Cody Burney, Regan Vaughn, Amber E. Hales, Derek Østbye, Truls Ward, Dianne. (2018, 2018). Physical activity and sedentary behaviors of children in family child care homes: Are there opportunities for improvement? *Pediatric Exercise Science, 30*(4), 529-536. https://doi.org/10.1123/pes.2018-0040

363. McCrady-Spitzer, S. K. S., V. Manohar, C. U. Levine, J. A. (2016, 2016). Low-cost, scalable classroom-based approach to promoting physical activity in preschool children. *Journal of Childhood Obesity, 1*(2). https://doi.org/10.21767/2572-5394.10008

364. McCullough, A. K. D., H. Garber, C. E. (2018, Dec). Interactive dyadic physical activity and spatial proximity patterns in 2-year-olds and their parents. *Children-Basel, 5*(12). https://doi.org/10.3390/children5120167

365. McGee, M., Unger, S., Hamilton, J., Birken, C. S., Pausova, Z., Vanderloo, L. M., Bando, N., & O'Connor, D. L. (2020, 2020). Lean mass accretion in children born very low birth weight is significantly associated with estimated changes from sedentary time to light physical activity. *Pediatric Obesity, 15*(5).

366. McIver, K. L., Pate, R. R., Dowda, M., Johnson, S. B., Yang, J., Butterworth, M., & Liu, X. (2020, 2020). Cross-country comparisons of physical activity and sedentary behavior among 5-year-old children. *International Journal of Pediatrics, 2020*, 7912894.

367. McNeill, J., Howard, S. J., Vella, S. A., & Cliff, D. P. (2020, 2020). Compliance with the 24-hour movement guidelines for the early years: Cross-sectional and longitudinal associations with executive function and psychosocial health in preschool children. *Journal of Science & Medicine in Sport, 23*(9), 846-853.

368. McNeill, J., Howard, S. J., Vella, S. A., & Cliff, D. P. (2020, 2020). Longitudinal associations of physical activity and modified organized sport participation with executive function and psychosocial health in preschoolers. *Journal of Sports Sciences, 38*(24), 2858-2865.

369. McNeill, J. H., S. J. Vella, S. A. Santos, R. Cliff, D. P. (2018, Oct). Physical activity and modified organized sport among preschool children: Associations with cognitive and psychosocial health. *Mental Health and Physical Activity, 15*, 45-52. https://doi.org/10.1016/j.mhpa.2018.07.001

370. Mehtala, M. A. S., A. Soini, A. Tammelin, T. Kulmala, J. Villberg, J. Nissinen, K. Poskiparta, M. (2017, 2017). The effect of the cluster randomized hippa intervention on childcare children's overall physical activity. *Baltic Journal of Health and Physical Activity, 9*(4), 89-111. https://doi.org/10.29359/BJHPA.09.4.08

371. Mei, H. J., E. Hagstromer, M. Xiong, Y. Zhang, L. Zhang, J. Marcus, C. (2016, 2016). Physical activity levels in chinese one-year-old children and their parents, an early stopp china study. *PLoS ONE [Electronic Resource], 11*(4), e0153605. https://doi.org/10.1371/journal.pone.0153605

372. Mendoza, J. A. B., T. Jaramillo, S. Fesinmeyer, M. D. Haal , W. Thompson, D. Nicklas, T. A. (2016, 2016). Fit 5 kids tv reduction program for latino preschoolers: A cluster randomized controlled trial. *American Journal of Preventive Medicine, 50*(5), 584-592.

373. Mendoza, J. A. M., J. Chen, T. A. Nicklas, T. A. Baranowski, T. (2013, 2013). Convergent validity of preschool children's television viewing measures among low-income latino families: A cross-sectional study. *Childhood Obesity, 9*(1), 29-34.

374. Mendoza, J. A. M., J. Chen, T. A. Nicklas, T. A. Baranowski, T. (2014, 2014). Correlates of adiposity among latino preschool children. *Journal of Physical Activity & Health, 11*(1), 195-198. https://doi.org/10.1123/jpah.2012-0018

375. Meredith-Jones, K., Galland, B., Haszard, J., Gray, A., Sayers, R., Hanna, M., Taylor, B., & Taylor, R. (2019, 2019). Do young children consistently meet 24-h sleep and activity guidelines? A longitudinal analysis using actigraphy. *International Journal of Obesity, 43*(12), 2555-2564.

376. Meredith-Jones, K. H., J. Moir, C. Heath, A. L. Lawrence, J. Gall , B. Taylor, B. Gray, A. Sayers, R. Taylor, R. (2018, 2018). Physical activity and inactivity trajectories associated with body composition in pre-schoolers. *International Journal of Obesity, 42*(9), 1621-1630.

377. Meredith-Jones, K. W., Sheila Gall , Barbara Kennedy, Gavin Taylor, Rachael. (2016, 2016). 24 h accelerometry: Impact of sleep-screening methods on estimates of sedentary behaviour and physical activity while awake. *Journal of Sports Sciences, 34*(7), 679-685.

378. Metcalf, B. S. J., A. N. Hosking, J. Voss, L. D. Sattar, N. Wilkin, T. J. (2009, 2009). Objectively measured physical activity and its association with adiponectin and other novel metabolic markers: A longitudinal study in children (earlybird 38). *Diabetes Care, 32*(3), 468-473.

379. Michaud, L. T., F. Beghin, L. El Rifai, N. Guimber, D. Turck, D. Gottr , F. (2009, 2009). Influence of esophageal ph recording on physical activity in children. *Journal of Pediatric Gastroenterology & Nutrition, 48*(4), 426-430. https://doi.org/10.1097/mpg.0b013e31817f2827

380. Michels, N. S., K. Marques-Vidal, P. M. Nydegger, A. Puder, J. J. (2016, 2016). Psychosocial quality-of-life, lifestyle and adiposity: A longitudinal study in pre-schoolers (ballabeina study). *International Journal of Behavioral Medicine, 23*(3), 383-392.

381. Mickle, K. J. C., D. P. Munro, B. J. Okely, A. D. Steele, J. R. Mickle, Karen J. Cliff, Dylan P. Munro, Bridget J. Okely, Anthony D. Steele, Julie R. (2011, 2011). Relationship between plantar pressures, physical activity and sedentariness among preschool children. *Journal of Science & Medicine in Sport, 14*(1), 36-41. https://doi.org/10.1016/j.jsams.2010.05.005

382. Migueles, J. H. C.-S., Cristina Henriksson, Pontus Ortega, Francisco B. Delisle NystrÖM, Christine LÖF, Marie. (2019, 2019). Accelerometer data processing and energy expenditure estimation in preschoolers. *Medicine & Science in Sports & Exercise, 51*(3), 590-598. https://doi.org/10.1249/MSS.0000000000001797

383. Moir, C. M.-J., K. Taylor, B. J. Gray, A. Heath, A. M. Dale, K. Gall , B. Lawrence, J. Sayers, R. M. Taylor, R. W. (2016, 2016). Early intervention to encourage physical activity in infants and toddlers: A randomized controlled trial. *Medicine & Science in Sports & Exercise, 48*(12), 2446-2453. https://doi.org/10.1249/MSS.0000000000001055

384. Møller, N. C. C., Line B. Mølgaard, Christian Ejlerskov, Katrine T. Pfeiffer, Karin A. Michaelsen, Kim F. Møller, Niels Christian Christensen, Line B. Mølgaard, Christian Ejlerskov, Katrine T. Pfeiffer, Karin A. Michaelsen, Kim F. (2017, 2017). Descriptive analysis of preschool physical activity and sedentary behaviors - a cross sectional study of 3-year-olds nested in the skot cohort. *BMC Public Health, 17*, 1-12. https://doi.org/10.1186/s12889-017-4521-3

385. Moore, J. B. B., Michael W. Brazendale, Keith Blair, Steven N. Pate, Russell R. Andersen, Lars B. Anderssen, Sigmund A. GrØNtved, Anders Hallal, Pedro C. Kordas, Katarzyna Kriemler, Susi Reilly, John J. Sardinha, Luis B. (2017, 2017). Associations of vigorous-intensity physical activity with biomarkers in youth. *Medicine & Science in Sports & Exercise, 49*(7), 1366-1374. https://doi.org/10.1249/MSS.0000000000001249

386. Mota, J. G., Clark, C. C. T., Bezerra, T. A., Lemos, L., Reuter, C. P., Mota, J. A. P. S., Duncan, M. J., & Martins, C. M. D. L. (2020, 2020). Twenty-four-hour movement behaviours and fundamental movement skills in preschool children: A compositional and isotemporal substitution analysis. *Journal of Sports Sciences, 38*(18), 2071-2079.

387. Mota, J. S.-M. a., L. Silva, J. M. Dos Santos, S. S. Vale, S. (2012, 2012). Influence of body fat and level of physical activity on rate-pressure product at rest in preschool children. *American Journal of Human Biology, 24*(5), 661-665. https://doi.org/10.1002/ajhb.22294

388. Mota, J. S. D. S., S. Santos, A. Seabra, A. Vale, S. (2016, 2016). Association between sedentary behavior time and waist-to-height ratio in preschool children. *American Journal of Human Biology, 28*(5), 746-748. https://doi.org/10.1002/ajhb.22851

389. Nascimento-Ferreira, M. V. D. M., Augusto César Ferreira Toazza-Oliveira, Paulo Vinícius Forjaz, Claudia L. M. Aristizabal, Juan Carlos Santaliesra-Pasías, Alba M. Lepera, C ela Nascimento-Junior, Walter Viana Skapino, Estela Delgado, Carlos Alberto Moreno, Luis Alberto Carvalho, Heráclito Barbosa. (2018, 2018). Reliability and validity of a questionnaire for physical activity assessment in south american children and adolescents: The saycare study. *Obesity, 26*, S23-S30. https://doi.org/10.1002/oby.22116

390. Nazaruk, S. K.-N., H. Waszczuk, J. Marchel, J. Chova, L. G. Martinez, A. L. Torres, I. C. (2017). Physical activity of children attending kindergartens in poland in the context of selected socio-demographic factors. In (pp. 2760-2765).

391. Nazaruk, S. T., Ewa. (2018, 2018). Do preschool institutions in poland provide children with the optimal development in the field of physical activity? *Early Child Development and Care*, No Pagination Specified-No Pagination Specified. https://doi.org/10.1080/03004430.2018.1555822

392. Nazaruk, S. W., J. Marchel, J. Kowaluk-Nikitin, H. Klim-Klimaszewska, A. (2018, 2018). The level of physical activity of children in kindergarten in the light of selected individual factors. *Problems of Education in the 21st Century, 76*(1), 58-68.

393. Neshteruk, C. D., Mazzucca, S., Vaughn, A. E., Jones, D. J., & Ward, D. S. (2020, 2020). Identifying patterns of physical activity and screen time parenting practices and associations with preschool children's physical activity and adiposity. *Preventive Medicine Reports, 18*, 101068.

394. Neshteruk, C. D. M., S. Ostbye, T. Ward, D. S. (2018, 2018). The physical environment in family childcare homes and children's physical activity. *Child: Care, Health & Development, 44*(5), 746-752. https://doi.org/10.1111/cch.12578

395. Ng, M., Rosenberg, M., Thornton, A., Lester, L., Trost, S. G., Bai, P., & Christian, H. (2020, 2020). The effect of upgrades to childcare outdoor spaces on preschoolers' physical activity: Findings from a natural experiment. *International journal of environmental research and public health, 17*(2).

396. Nicaise, V. K., David Reuben, Karen Sallis, James F. (2012, 2012). Evaluation of a redesigned outdoor space on preschool children's physical activity during recess. *Pediatric Exercise Science, 24*(4), 507-518. https://doi.org/10.1123/pes.24.4.507

397. Nicolai Ré, A. H., Okely, A. D., Logan, S. W., da Silva, M. M. L. M., Cattuzzo, M. T., & Stodden, D. F. (2020, 2020). Relationship between meeting physical activity guidelines and motor competence among low-income school youth. *Journal of Science & Medicine in Sport, 23*(6), 591-595.

398. Niederer, I. K., S. Zahner, L. Burgi, F. Ebenegger, V. Marques, P. Puder, J. J. (2012, 2012). Bmi group-related differences in physical fitness and physical activity in preschool-age children: A cross-sectional analysis. *Research Quarterly for Exercise & Sport, 83*(1), 12-19. https://doi.org/10.1080/02701367.2012.10599820

399. Nilsen, A. K. O., Anderssen, S. A., Johannessen, K., Aadland, K. N., Ylvisaaker, E., Loftesnes, J. M., & Aadland, E. (2020, 2020). Bi-directional prospective associations between objectively measured physical activity and fundamental motor skills in children: A two-year follow-up. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1).

400. Nilsen, A. K. O., Anderssen, S. A., Loftesnes, J. M., Johannessen, K., Ylvisaaker, E., & Aadland, E. (2020, 2020). The multivariate physical activity signature associated with fundamental motor skills in preschoolers. *Journal of Sports Sciences, 38*(3), 264-272.

401. Nilsen, A. K. O. A., S. A. Resal , G. K. Johannessen, K. Ylvisaaker, E. Aadl , E. (2019, 2019). Boys, older children, and highly active children benefit most from the preschool arena regarding moderate-to-vigorous physical activity: A cross-sectional study of norwegian preschoolers. *Preventive Medicine Reports, 14*, 100837.

402. Nilsen, A. K. O. A., S. A. Ylvisaaker, E. Johannessen, K. Aadl , E. (2019, 2019). Physical activity among norwegian preschoolers varies by sex, age, and season. *Scandinavian Journal of Medicine & Science in Sports, 29*(6), 862-873.

403. O'Connor, T. M. C., E. Robles, J. Lee, R. E. Kerr, J. Butte, N. Mendoza, J. A. Thompson, D. Baranowski, T. (2013, 2013). Feasibility study to objectively assess activity and location of hispanic preschoolers: A short communication. *Geospatial Health, 7*(2), 375-380.

404. O'Connor, T. M. C., E. Hughes, S. O. Robles, J. Thompson, D. I. Mendoza, J. A. Baranowski, T. Lee, R. E. (2014, 2014). Psychometrics of the preschooler physical activity parenting practices instrument among a latino sample. *International Journal of Behavioral Nutrition & Physical Activity, 11*, 3. https://doi.org/10.1186/1479-5868-11-3

405. O'Dwyer, M. F., Stuart J. Ridgers, Nicola Diane Knowles, Zoe Rebecca Foweather, Lawrence Stratton, Gareth. (2014, 2014). Patterns of objectively measured moderate-to-vigorous physical activity in preschool children. *Journal of Physical Activity & Health, 11*(6), 1233-1238. https://doi.org/10.1123/jpah.2012-0163

406. O'Dwyer, M. V. F., L. Stratton, G. Ridgers, N. D. (2011, 2011). Physical activity in non-overweight and overweight uk preschool children: Preliminary findings and methods of the active play project. *Science & Sports, 26*(6), 345-349. https://doi.org/10.1016/j.scispo.2011.01.006

407. O'Dwyer, M. V. F., S. J. Knowles, Z. Stratton, G. (2012, 2012). Effect of a family focused active play intervention on sedentary time and physical activity in preschool children. *International Journal of Behavioral Nutrition & Physical Activity, 9*, 117. https://doi.org/10.1186/1479-5868-9-117

408. O'Neill, J. R. P., K. A. Dowda, M. Pate, R. R. (2016, 2016). In-school and out-of-school physical activity in preschool children. *Journal of Physical Activity & Health, 13*(6), 606-610. https://doi.org/10.1123/jpah.2015-0245

409. O'Dwyer, M. V. F., S. J. Ridgers, N. D. Knowles, Z. R. Foweather, L. Stratton, G. (2013, 2013). Effect of a school-based active play intervention on sedentary time and physical activity in preschool children. *Health Education Research, 28*(6), 931-942. https://doi.org/10.1093/her/cyt097

410. Obeid, J. N., T. Gabel, L. Timmons, B. W. (2011, 2011). Physical activity in ontario preschoolers: Prevalence and measurement issues. *Applied Physiology, Nutrition, & Metabolism = Physiologie Appliquee, Nutrition et Metabolisme, 36*(2), 291-297. https://doi.org/10.1139/h11-002

411. Ocansey, M. E., Pulakka, A., Adu-Afarwuah, S., Young, R. R., Kumordzie, S. M., Okronipa, H., Oaks, B. M., Dewey, K. G., & Prado, E. L. (2019, 2019). The effects of supplementing maternal and infant diets with lipid-based nutrient supplements on physical activity and sedentary behaviour at preschool age in ghana. *British Journal of Nutrition, 122*(8), 884-894.

412. Oftedal, S. B., Kristie L. Davies, Peter S. W. Ware, Robert S. Boyd, Roslyn N. (2015, 2015). Sedentary and active time in toddlers with and without cerebral palsy. *Medicine & Science in Sports & Exercise, 47*(10), 2076-2083. https://doi.org/10.1249/Mss.0000000000000653

413. Ogden, M. R., N. Faurholt-Jepsen, D. Skau, J. Friis, H. Ritz, C. Brage, S. Chamnan, C. (2013, 2013). Volume and patterns of physical activity in rural cambodian children aged 15-months. *Annals of Nutrition and Metabolism, 63*, 982-983. https://doi.org/10.1159/000354245

414. Ojiambo, R. K., K. Veidebaum, T. Reilly, J. Verbestel, V. Huybrechts, I. Sioen, I. Casajus, J. A. Moreno, L. A. Vicente-Rodriguez, G. Bammann, K. Tubic, B. M. Marild, S. Westerterp, K. Pitsiladis, Y. P. Consortium, Idefics. (2012, 2012). Validity of hip-mounted uniaxial accelerometry with heart-rate monitoring vs. Triaxial accelerometry in the assessment of free-living energy expenditure in young children: The idefics validation study. *Journal of Applied Physiology, 113*(10), 1530-1536.

415. Okely, A. D., Stanley, R. M., Jones, R. A., Cliff, D. P., Trost, S. G., Berthelsen, D., Salmon, J., Batterham, M., Eckermann, S., Reilly, J. J., Brown, N., Mickle, K. J., Howard, S. J., Hinkley, T., Janssen, X., Chandler, P., Cross, P., & Gowers, F. (2020, 2020). 'Jump start' childcare-based intervention to promote physical activity in pre-schoolers: Six-month findings from a cluster randomised trial. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1).

416. Olesen, L. G. K., P. L. Korsholm, L. Froberg, K. (2013, 2013). Physical activity in children attending preschools. *Pediatrics, 132*(5), e1310-1318. https://doi.org/10.1542/peds.2012-3961

417. Olesen, L. G. K., P. L. Ried-Larsen, M. Grontved, A. Froberg, K. (2014, 2014). Physical activity and motor skills in children attending 43 preschools: A cross-sectional study. *BMC Pediatrics, 14*, 229. https://doi.org/https://doi.org/10.1186/1471-2431-14-229

418. Oliver, M. S., Grant M. Schluter, Philip J. (2009, 2009). Accelerometry to assess preschooler's free-play: Issues with count thresholds and epoch durations. *Measurement in physical education and exercise science, 13*(4), 181-190. https://doi.org/10.1080/13614530903260047

419. Oliver, M. S., G. M. Schluter, P. J. Oliver, Melody Schofield, Grant M. Schluter, Philip J. (2010, 2010). Parent influences on preschoolers' objectively assessed physical activity. *Journal of Science & Medicine in Sport, 13*(4), 403-409. https://doi.org/10.1016/j.jsams.2009.05.008

420. Oliver, M. S., P. J. Schofield, G. (2011, 2011). A new approach for the analysis of accelerometer data measured on preschool children. *Journal of Physical Activity & Health, 8*(2), 296-304. https://doi.org/10.1123/jpah.8.2.296

421. Oliver, M. S., P. J. Schofield, G. M. (2012, 2012). Body size, physical activity, and exposure to television in preschoolers. *Open Journal of Preventive Medicine, 2*(3), 359-363. https://doi.org/10.4236/ojpm.2012.23052

422. Ostbye, T. K., K. M. Stroo, M. Lovelady, C. A. Evenson, K. R. Peterson, B. L. Bastian, L. A. Swamy, G. K. West, D. G. Brouwer, R. J. N. Zucker, N. L. (2012, Sep). Parent-focused change to prevent obesity in preschoolers: Results from the kan-do study. *Preventive Medicine, 55*(3), 188-195.

423. Ostbye, T. M., R. Stroo, M. Lovelady, C. Brouwer, R. Zucker, N. Fuemmeler, B. Østbye, T. (2013, 2013). The effect of the home environment on physical activity and dietary intake in preschool children. *International Journal of Obesity, 37*(10), 1314-1321.

424. Pagels, P. B., C. Raustorp, A. (2011, 2011). Comparison of pedometer and accelerometer measures of physical activity during preschool time on 3- to 5-year-old children. *Acta Paediatrica, 100*(1), 116-120. https://doi.org/10.1111/j.1651-2227.2010.01962.x

425. Palmer, K. K. C., N. Chinn, K. M. Robinson, L. E. (2017, Jun). Measuring school-day physical activity using ankle accelerometry in preschoolers: A pilot study. *Journal of Sport & Exercise Psychology, 39*, S86-S87. https://doi.org/10.1123/jsep.39.3.s1

426. Palmer, K. K. C., K. M. Robinson, L. E. (2019, 2019). The effect of the champ intervention on fundamental motor skills and outdoor physical activity in preschoolers. *Journal of Sport & Health Science, 8*(2), 98-105. https://doi.org/10.1016/j.jshs.2018.12.003

427. Palmer, K. K. M., Abigail L. Robinson, Leah E. (2017, 2017). Impact of structured movement time on preschoolers' physical activity engagement. *Early Childhood Education Journal, 45*(2), 201-206. https://doi.org/10.1007/s10643-016-0778-x

428. Parekh, N. H., P. Delisle Nystrom, C. Silfvernagel, K. Ruiz, J. R. Ortega, F. B. Pomeroy, J. Lof, M. (2018, 2018). Associations of parental self-efficacy with diet, physical activity, body composition, and cardiorespiratory fitness in swedish preschoolers: Results from the ministop trial. *Health Education & Behavior, 45*(2), 238-246. https://doi.org/10.1177/1090198117714019

429. Pate, R. R., O'Neill, J. R., Brown, W. H., Pfeiffer, K. A., Dowda, M., & Addy, C. L. (2015). Prevalence of compliance with a new physical activity guideline for preschool-age children. *Childhood Obesity, 11*(4), 415-420. https://doi.org/10.1089/chi.2014.0143

430. Pate, R. R. B., William H. Pfeiffer, Karin A. Howie, Erin K. Saunders, Ruth P. Addy, Cheryl L. Dowda, Marsha. (2016, 2016). An intervention to increase physical activity in children: A randomized controlled trial with 4-year-olds in preschools. *American Journal of Preventive Medicine, 51*(1), 12-22.

431. Pate, R. R. O. N., Jennifer R. Byun, Wonwoo McIver, Kerry L. Dowda, Marsha Brown, William H. (2014, 2014). Physical activity in preschool children: Comparison between montessori and traditional preschools. *Journal of School Health, 84*(11), 716-721.

432. Peplies, J. B., C. Gunther, K. Fraterman, A. Russo, P. Veidebaum, T. Tornaritis, M. De Henauw, S. Marild, S. Molnar, D. Moreno, L. A. Ahrens, W. consortium, Idefics. (2016, 2016). Longitudinal associations of lifestyle factors and weight status with insulin resistance (homa-ir) in preadolescent children: The large prospective cohort study idefics. *International Journal of Behavioral Nutrition & Physical Activity, 13*(1), 97. https://doi.org/10.1186/s12966-016-0424-4

433. Pereira, J. R., Sousa-Sá, E., Zhang, Z., Cliff, D. P., & Santos, R. (2020, 2020). Concurrent validity of the actigraph gt3x+ and activpal for assessing sedentary behaviour in 2-3-year-old children under free-living conditions. *Journal of Science & Medicine in Sport, 23*(2), 151-156.

434. Petersen, T. L., Brond, J. C., Kristensen, P. L., Aadland, E., Grontved, A., & Jepsen, R. (2020, 2020). Resemblance in accelerometer-assessed physical activity in families with children: The lolland-falster health study. *International Journal of Behavioral Nutrition and Physical Activity, 17*(1).

435. Pfeiffer, K. A. D., M. McIver, K. L. Pate, R. R. (2009, 2009). Factors related to objectively measured physical activity in preschool children. *Pediatric Exercise Science, 21*(2), 196-208.

436. Pitchford, E. A. K., L. R. Kwon, H. J. Ulrich, D. A. (2017, 2017). Minimum accelerometer wear time in infants: A generalizability study. *Journal of Physical Activity & Health, 14*(6), 421-428. https://doi.org/10.1123/jpah.2016-0395

437. Plevnik, M. S., B. Pisot, R. (2014, 2014). The assessment of climbing skills in four-year-old children. *Croatian Journal of Education-Hrvatski Casopis Za Odgoj I Obrazovanje, 16*(3), 677-697.

438. Prioreschi, A. B., S. Westgate, K. Micklesfield, L. K. (2018, 2018). Describing the diurnal relationships between objectively measured mother and infant physical activity. *International Journal of Behavioral Nutrition & Physical Activity, 15*(1), 59. https://doi.org/10.1186/s12966-018-0692-2

439. Prioreschi, A. r. B., Soren Hesketh, Kylie D. Hnatiuk, Jill Westgate, Kate Micklesfield, Lisa K. (2017, 2017). Describing objectively measured physical activity levels, patterns, and correlates in a cross sectional sample of infants and toddlers from south africa. *International Journal of Behavioral Nutrition & Physical Activity, 14*(1), 1-14. https://doi.org/10.1186/s12966-017-0633-5

440. Proudfoot, N. A. K.-D., S. Cairney, J. Bray, S. R. MacDonald, M. J. Timmons, B. W. (2019, 2019). Physical activity and trajectories of cardiovascular health indicators during early childhood. *Pediatrics, 144*(1). https://doi.org/10.1542/peds.2018-2242

441. Proudfoot, N. A. S., N. King-Dowling, S. Di Cristofaro, N. MacDonald, M. J. Timmons, B. W. (2016, 2016). Intensity of physical activity impacts the rate of change of arterial stiffness in the early years...2016 north american society for pediatric exercise medicine (naspem) biennial meeting, knoxville, tennessee. *Pediatric Exercise Science, 28*, 24-24. https://doi.org/10.1123/pes.2016.0242

442. Pulakka, A. A., U. Cheung, Y. B. Dewey, K. G. Maleta, K. Vosti, S. A. Ashorn, P. (2015, 2015). Effect of 12-month intervention with lipid-based nutrient supplements on physical activity of 18-month-old malawian children: A randomised, controlled trial. *European Journal of Clinical Nutrition, 69*(2), 173-178.

443. Pulakka, A. C., Y. B. Ashorn, U. Penpraze, V. Maleta, K. Phuka, J. C. Ashorn, P. (2013, 2013). Feasibility and validity of the actigraph gt3x accelerometer in measuring physical activity of malawian toddlers. *Acta Paediatrica, 102*(12), 1192-1198. https://doi.org/10.1111/apa.12412

444. Pulakka, A. C., Y. B. Maleta, K. Dewey, K. G. Kumwenda, C. Bendabenda, J. Ashorn, U. Ashorn, P. (2017, 2017). Effect of 12-month intervention with lipid-based nutrient supplement on the physical activity of malawian toddlers: A randomised, controlled trial. *British Journal of Nutrition, 117*(4), 511-518.

445. Quan, M. Z., H. Zhang, J. Zhou, T. Zhang, J. Zhao, G. Fang, H. Sun, S. Wang, R. Chen, P. (2018, 2018). Preschoolers' technology-assessed physical activity and cognitive function: A cross-sectional study. *Journal of Clinical Medicine, 7*(5), 08. https://doi.org/10.3390/jcm7050108

446. Quan, M. Z., H. Zhang, J. Zhou, T. Zhang, J. Zhao, G. Fang, H. Sun, S. Wang, R. Chen, P. (2019, 2019). Are preschool children active enough in shanghai: An accelerometer-based cross-sectional study. *BMJ Open, 9*(4), e024090.

447. Raustorp, A. P., P. Boldemann, C. Cosco, N. Soderstrom, M. Martensson, F. (2012, 2012). Accelerometer measured level of physical activity indoors and outdoors during preschool time in sweden and the united states. *Journal of Physical Activity & Health, 9*(6), 801-808. https://doi.org/10.1123/jpah.9.6.801

448. Ray, C., Figuereido, R., Vepsalainen, H., Lehto, R., Pajulahti, R., Skaffari, E., Sainio, T., Hiltunen, P., Lehto, E., Korkalo, L., Saaksjarvi, K., Sajaniemi, N., Erkkola, M., & Roos, E. (2020, 2020). Effects of the preschool-based family-involving dagis intervention program on children's energy balance-related behaviors and self-regulation skills: A clustered randomized controlled trial. *Nutrients, 12*(9).

449. Ray, C. C., K. Hesketh, K. D. (2019, 2019). Key messages in an early childhood obesity prevention intervention: Are they recalled and do they impact children's behaviour? *International Journal of Environmental Research & Public Health [Electronic Resource], 16*(9), 02.

450. Raza, H. Z., Shang-Ming Todd, Charlotte Christian, Danielle Marchant, Emily Morgan, Kelly Khanom, Ashrafunnesa Hill, Rebecca Lyons, Ronan A. Brophy, Sinead. (2019, 2019). Predictors of objectively measured physical activity in 12-month-old infants: A study of linked birth cohort data with electronic health records. *Pediatric Obesity, 14*(7), N.PAG-N.PAG. https://doi.org/10.1111/ijpo.12512

451. Razak, L. A. Y., S. L. Wiggers, J. Morgan, P. J. Jones, J. Finch, M. Sutherl , R. Lecathelnais, C. Gillham, K. Clinton-McHarg, T. Wolfenden, L. (2018, 2018). Impact of scheduling multiple outdoor free-play periods in childcare on child moderate-to-vigorous physical activity: A cluster randomised trial. *International Journal of Behavioral Nutrition & Physical Activity, 15*(1), 34. https://doi.org/10.1186/s12966-018-0665-5

452. Remmers, T. S., E. F. Gubbels, J. S. de Vries, S. I. Mommers, M. Penders, J. Kremers, S. P. Thijs, C. (2014, 2014). Relationship between physical activity and the development of body mass index in children. *Medicine & Science in Sports & Exercise, 46*(1), 177-184. https://doi.org/10.1249/MSS.0b013e3182a36709

453. Ricardo, L. I. C., da Silva, I. C. M., Leao, O. A. D., Domingues, M. R., & Wehrmeister, F. C. (2019, 2019). Objectively measured physical activity in one-year-old children from a brazilian cohort: Levels, patterns and determinants. *International Journal of Behavioral Nutrition and Physical Activity, 16*(1).

454. Ricardo, L. I. C. I., D. A. Silva Martins, R. C. Wendt, A. Goncalves, H. Hallal, P. R. C. Wehrmeister, F. C. (2018, 2018). Protocol for objective measurement of infants' physical activity using accelerometry. *Medicine & Science in Sports & Exercise, 50*(5), 1084-1092. https://doi.org/10.1249/MSS.0000000000001512

455. Rice, K. R. (2013). *Physical activity in children attending family child care homes* ProQuest Information & Learning]. US.

456. Rice, K. R. J., B. Trost, S. G. (2013, 2013). Validity of family child care providers' proxy reports on children's physical activity. *Childhood Obesity, 9*(5), 393-398.

457. Rice, K. R. T., Stewart G. (2014, 2014). Physical activity levels among children attending family day care. *Journal of nutrition education and behavior, 46*(3), 197-202.

458. Ridgers, N. D. T., A. Crawford, D. Salmon, J. (2012, 2012). Five-year changes in school recess and lunchtime and the contribution to children's daily physical activity. *British Journal of Sports Medicine, 46*(10), 741-746.

459. Robinson, J. C. T., Melissa L. Duck, Angela Klamm, Melissa. (2019, 2019). Feasibility and effectiveness of two built environmental interventions on physical activity among 3–5-year-old preschoolers. *Journal for Specialists in Pediatric Nursing, 24*(3), N.PAG-N.PAG. https://doi.org/10.1111/jspn.12262

460. Rohde, J. F. B., Benjamin Berglind, Daniel Hansson, Lena M. Frederiksen, Peder Mortensen, Erik Lykke Heitmann, Berit Lilienthal Rasmussen, Finn Friis, Rohde Jeanett Benjamin, Bohman Daniel, Berglind Hansson Lena, M. Peder, Frederiksen Lykke, Mortensen Erik Lilienthal, Heitmann Berit Finn, Rasmussen. (2018, 2018). Cross-sectional associations between maternal self-efficacy and dietary intake and physical activity in four-year-old children of first-time swedish mothers. *Appetite, 125*, 131-138. https://doi.org/10.1016/j.appet.2018.01.026

461. Roscoe, C. M. P. J., Rob S. Duncan, Michael J. (2019, 2019). Accelerometer-based physical activity levels, fundamental movement skills and weight status in british preschool children from a deprived area. *European Journal of Pediatrics, 178*(7), 1043-1052.

462. Ross, K. R. H., M. A. Storfer-Isser, A. Kibler, A. M. Johnson, N. L. Rosen, C. L. Kercsmar, C. M. Redline, S. (2009, 2009). Obesity and obesity related co-morbidities in a referral population of children with asthma. *Pediatric Pulmonology, 44*(9), 877-884.

463. Ross, S. T. D., Marsha Saunders, Ruth Pate, Russell. (2013, 2013). Double dose: The cumulative effect of tv viewing at home and in preschool on children's activity patterns and weight status. *Pediatric Exercise Science, 25*(2), 262-272. https://doi.org/10.1123/pes.25.2.262

464. Roth, K. K., Susi Lehmacher, Walter Ruf, Katharina C. Graf, Christine Hebestreit, Helge. (2015, 2015). Effects of a physical activity intervention in preschool children. *Medicine & Science in Sports & Exercise, 47*(12), 2542-2551. https://doi.org/10.1249/MSS.0000000000000703

465. Rottger, K. G., E. Kreuser, F. Assl er, L. Gollhofer, A. Korsten-Reck, U. (2014, 2014). Physical activity in different preschool settings: An exploratory study. *Journal of Obesity, 2014*, 321701.

466. Ruiz, R. G., Sabina B. Buchowski, Maciej S. Lambert, Warren Barkin, Shari L. (2011, 2011). The relationship between hispanic parents and their preschool-aged children's physical activity. *Pediatrics, 127*(5), 888-895.

467. Ruiz, R. M. S., Evan C. Tracy, Dustin a, Jorge A. Economos, Christina D. JaKa, Megan M. Evenson, Kelly R. Buchowski, Maciej S. Barkin, Shari L. (2018, 2018). Novel patterns of physical activity in a large sample of preschool-aged children. *BMC Public Health, 18*, 242-242.

468. Ruiz, R. M. T., Dustin Sommer, Evan C. Barkin, Shari L. (2013, 2013). A novel approach to characterize physical activity patterns in preschool-aged children. *Obesity (19307381), 21*(11), 2197-2203.

469. Rundle, A. G., I. F. Mellins, R. B. Ashby-Thompson, M. Hoepner, L. Jacobson, J. S. (2009, 2009). Physical activity and asthma symptoms among new york city head start children. *Journal of Asthma, 46*(8), 803-809.

470. Said-Mohamed, R. B., J. Y. Ndzana, A. C. Pasquet, P. (2012, 2012). Is overweight in stunted preschool children in cameroon related to reductions in fat oxidation, resting energy expenditure and physical activity? *PLoS ONE [Electronic Resource], 7*(6), e39007. https://doi.org/10.1371/journal.pone.0039007

471. Santaliestra-Pasias, A. M., Gonzalez-Gil, E. M., Pala, V., Intemann, T., Hebestreit, A., Russo, P., Van Aart, C., Rise, P., Veidebaum, T., Molnar, D., Tornaritis, M., Eiben, G., Moreno, L. A., & Consortium, I. (2020, 2020). Predictive associations between lifestyle behaviours and dairy consumption: The idefics study. *Nutrition, metabolism, and cardiovascular diseases : NMCD, 30*(3), 514-522.

472. Santaliestra-Pasías, A. M. D., Jaime E. Llamas Sprengeler, Ole Hebestreit, Antje De Henauw, Stefaan Eiben, Gabriele Felsö, Regina Lauria, Fabio Tornaritis, Michael Veidebaum, Toomas Pala, Valeria Moreno, Luis A. Santaliestra-Pasías, Alba M. Felsö, Regina. (2018, 2018). Food and beverage intakes according to physical activity levels in european children: The idefics (identification and prevention of dietary and lifestyle induced health effects in children and infants) study. *Public Health Nutrition, 21*(9), 1717-1725.

473. Santos, R. Z., Z. Pereira, J. R. Sousa-Sa, E. Cliff, D. P. Okely, A. D. (2017, 2017). Compliance with the australian 24-hour movement guidelines for the early years: Associations with weight status. *BMC Public Health, 17*, 867.

474. Sarker, H. A., L. N. Borkhoff, C. M. Abreo, K. Tremblay, M. S. Lebovic, G. Maguire, J. L. Parkin, P. C. Birken, C. S. Collaboration, T. ARGet Kids. (2015, 2015). Validation of parent-reported physical activity and sedentary time by accelerometry in young children. *BMC Research Notes, 8*, 735.

475. Sarzynski, M. A. E., J. C. Welk, G. J. Tucker, J. Glenn, K. Rothschild, M. Heelan, K. (2010, 2010). Ace i/d genotype, habitual physical activity, and blood pressure in children. *Pediatric Exercise Science, 22*(2), 301-313. https://doi.org/10.1123/pes.22.2.301

476. Saunders, R. P., Dowda, M., Pfeiffer, K. A., Brown, W. H., & Pate, R. R. (2019, 2019). Childcare center characteristics moderate the effects of a physical activity intervention. *International journal of environmental research and public health, 17*(1).

477. Saunders, R. P. B., William H. Dowda, Marsha O'Neill, Jennifer R. McIver, Kerry Pate, Russell R. Pfeiffer, Karin Howie, Erin K. (2017, 2017). Evaluating and refining the conceptual model used in the study of health and activity in preschool environments (shapes) intervention. *Health Education & Behavior, 44*(6), 876-884. https://doi.org/10.1177/1090198116686334

478. Schlechter, C. R. R., R. R. Fees, B. S. Dzewaltowski, D. A. (2017, 2017). Preschool daily patterns of physical activity driven by location and social context. *Journal of School Health, 87*(3), 194-199. https://doi.org/10.1111/josh.12486

479. Schmutz, E. A., Leeger-Aschmann, C. S., Kakebeeke, T. H., Zysset, A. E., Messerli-Burgy, N., Stulb, K., Arhab, A., Meyer, A. H., Munsch, S., Puder, J. J., Jenni, O. G., & Kriemler, S. (2020, 2020). Motor competence and physical activity in early childhood: Stability and relationship. *Frontiers in Public Health, 8*.

480. Schmutz, E. A. H., S. R. Leeger-Aschmann, C. S. Kakebeeke, T. H. Zysset, A. E. Messerli-Burgy, N. Stulb, K. Arhab, A. Meyer, A. H. Munsch, S. Puder, J. J. Jenni, O. G. Kriemler, S. (2018, 2018). Physical activity and sedentary behavior in preschoolers: A longitudinal assessment of trajectories and determinants. *International Journal of Behavioral Nutrition & Physical Activity, 15*(1), 35. https://doi.org/10.1186/s12966-018-0670-8

481. Schmutz, E. A. L.-A., C. S. Radtke, T. Muff, S. Kakebeeke, T. H. Zysset, A. E. Messerli-Burgy, N. Stulb, K. Arhab, A. Meyer, A. H. Munsch, S. Puder, J. J. Jenni, O. G. Kriemler, S. (2017, 2017). Correlates of preschool children's objectively measured physical activity and sedentary behavior: A cross-sectional analysis of the splashy study. *International Journal of Behavioral Nutrition & Physical Activity, 14*(1), 1. https://doi.org/10.1186/s12966-016-0456-9

482. Schuna, J. M. L., G. Tucker, J. (2016, 2016). Seasonal changes in preschoolers' sedentary time and physical activity at childcare. *International Journal of Child Health and Nutrition, 5*(1), 17-24. https://doi.org/10.6000/1929-4247.2016.05.01.3

483. Schuna Jr, J. M. (2013). *Physical activity of preschool aged children during childcare: Examination of seasonal changes and an evaluation of a dance-based intervention* ProQuest Information & Learning]. US.

484. Scott-Andrews, K. Q., Wengrovius, C., & Robinson, L. E. (2020, 2020). Parents accurately perceive problematic eating behaviors but overestimate physical activity levels in preschool children. *Eating and Weight Disorders-Studies on Anorexia Bulimia and Obesity*.

485. Sebire, S. J. J., R. Wood, L. Thompson, J. L. Zahra, J. Lawlor, D. A. (2016, 2016). Examining a conceptual model of parental nurturance, parenting practices and physical activity among 5-6 year olds. *Social Science & Medicine, 148*, 18-24. https://doi.org/10.1016/j.socscimed.2015.11.022

486. Segura-Martínez, P., Molina-García, J., Queralt, A., del Mar Bernabé-Villodre, M., Martínez-Bello, D. A., & Martínez-Bello, V. E. (2020, 2020). An indoor physical activity area for increasing physical activity in the early childhood education classroom: An experience for enhancing young children's movement. *Early Childhood Education Journal*, No Pagination Specified-No Pagination Specified.

487. Senso, M. M. T., Stewart G. Crain, A. Lauren Seburg, Elisabeth M. Anderson, Julie D. Sherwood, Nancy E. (2015, 2015). Activity patterns of preschool-aged children at risk for obesity. *Journal of Physical Activity & Health, 12*(6), 861-868. https://doi.org/10.1123/jpah.2013-0503

488. Sharma, S. V. C., Ru-Jye Skala, Katherine Atteberry, Heather. (2011, 2011). Measuring physical activity in preschoolers: Reliability and validity of the system for observing fitness instruction time for preschoolers (sofit-p). *Measurement in physical education and exercise science, 15*(4), 257-273.

489. Shen, B. A. e., G. Milberger, S. Jen, K. L. (2013, 2013). An exploratory study of seasonality and preschoolers' physical activity engagement. *Journal of Physical Activity & Health, 10*(7), 993-999. https://doi.org/10.1123/jpah.10.7.993

490. Shen, B. R.-L., T. Janisse, H. Brogan, K. Danford, C. Jen, K. L. Shen, Bo Reinhart-Lee, Tamara Janisse, Heather Brogan, Kathryn Danford, Cynthia Jen, K. L. C. (2012, 2012). African american preschool children's physical activity levels in head start. *Research Quarterly for Exercise & Sport, 83*(2), 168-174. https://doi.org/10.1080/02701367.2012.10599847

491. Sherwood, N. E. J., M. M. Crain, A. L. Martinson, B. C. Hayes, M. G. Anderson, J. D. (2015, 2015). Pediatric primary care-based obesity prevention for parents of preschool children: A pilot study. *Childhood Obesity, 11*(6), 674-682.

492. Sigmund, E. S., D. El Ansari, W. (2009, 2009). Changes in physical activity in pre-schoolers and first-grade children: Longitudinal study in the czech republic. *Child: Care, Health & Development, 35*(3), 376-382. https://doi.org/10.1111/j.1365-2214.2009.00945.x

493. Sijtsma, A. S., H. Goris, A. H. Joosten, K. F. van Kessel, I. Corpeleijn, E. Sauer, P. J. (2013, 2013). Validation of the tracmord triaxial accelerometer to assess physical activity in preschool children. *Obesity, 21*(9), 1877-1883. https://doi.org/10.1002/oby.20401

494. Sijtsma, A. S., Pieter J. J. Corpeleijn, Eva. (2015, 2015). Parental correlations of physical activity and body mass index in young children-the gecko drenthe cohort. *International Journal of Behavioral Nutrition & Physical Activity, 12*, 1-7. https://doi.org/ARTN 132 10.1186/s12966-015-0295-0

495. Silva-Santos, S. r. S., Am Vale, Susana Mota, Jorge. (2017, 2017). Motor fitness and preschooler children obesity status. *Journal of Sports Sciences, 35*(17), 1704-1708.

496. Sisson, S. B. S., J. Li, J. Stephens, L. Campbell, J. E. Lora, K. R. Arnold, S. H. Horm, D. DeGrace, B. (2017, 2017). Tribally affiliated child-care center environment and obesogenic behaviors in young children. *Journal of the Academy of Nutrition & Dietetics, 117*(3), 433-440. https://doi.org/10.1016/j.jand.2016.10.015

497. Slaton, A., Kowalski, A. J., Zemanick, A., Kuhn, A. P., Hager, E. R., & Black, M. M. (2020, 2020). Motor competence and attainment of global physical activity guidelines among a statewide sample of preschoolers. *International journal of environmental research and public health, 17*(22).

498. Small, L. B.-M., Darya Gannon, Alex M. (2013, 2013). Physical activity of young overweight and obese children: Parent reports of child activity level compared with objective measures. *Western Journal of Nursing Research, 35*(5), 638-654.

499. Soini, A. (2015, 2015). Always on the move?: Measured physical activity of 3-year-old preschool children. *Studies in sport, physical education and health; 0356-1070; 216.*

500. Soini, A. T., Tuija Sääkslahti, Arja Watt, Anthony Villberg, Jari Kettunen, Tarja Mehtälä, Anette Poskiparta, Marita. (2014, 2014). Seasonal and daily variation in physical activity among three-year-old finnish preschool children. *Early Child Development and Care, 184*(4), 589-601. https://doi.org/10.1080/03004430.2013.804070

501. Solomon-Moore, E. S., S. J. Thompson, J. L. Zahra, J. Lawlor, D. A. Jago, R. (2016, 2016). Are parents' motivations to exercise and intention to engage in regular family-based activity associated with both adult and child physical activity? *BMJ Open Sport & Exercise Medicine, 2*(1), e000137. https://doi.org/10.1136/bmjsem-2016-000137

502. Song, M. D., N. F. Stoyles, S. Kim, Y. Lumeng, J. C. (2017, 2017). Associations between mother's and children's moderate-to-vigorous physical activity and sedentary time in the family context. *Preventive Medicine Reports, 8*, 197-203.

503. Sousa-Sa, E., Ruiz, J. R., Zhang, Z. G., Pereira, J. R., Veldman, S. L. C., Okely, A. D., & Santos, R. (2021, 2021). Sedentary time and blood pressure in australian toddlers: The get-up study longitudinal results. *Journal of Sports Sciences, 39*(2), 227-231.

504. Soyang, K. J., Kathleen F. Burns, Trudy L. Levy, Steven M. (2011, 2011). Association between light-intensity physical activity and adiposity in childhood. *Pediatric Exercise Science, 23*(2), 218-229. https://doi.org/10.1123/pes.23.2.218

505. Spittaels, H. V. C., E. Verbestel, V. De Meester, F. Van Dyck, D. Verloigne, M. Haerens, L. Deforche, B. Cardon, G. De Bourdeaudhuij, I. (2012, 2012). Objectively measured sedentary time and physical activity time across the lifespan: A cross-sectional study in four age groups. *International Journal of Behavioral Nutrition & Physical Activity, 9*, 149. https://doi.org/10.1186/1479-5868-9-149

506. St Laurent, C. W., Burkart, S., Rodheim, K., Marcotte, R., & Spencer, R. M. C. (2020, 2020). Cross-sectional associations of 24-hour sedentary time, physical activity, and sleep duration compositions with sleep quality and habits in preschoolers. *International journal of environmental research and public health, 17*(19).

507. Staiano, A. E. W., E. K. Allen, A. T. Jarrell, A. R. Martin, C. K. (2018, 2018). Screen-time policies and practices in early care and education centers in relationship to child physical activity. *Childhood Obesity, 14*(6), 341-348.

508. Statler, J., Wilk, P., Timmons, B. W., Colley, R., & Tucker, P. (2020, 2020). Habitual physical activity levels and sedentary time of children in different childcare arrangements from a nationally representative sample of canadian preschoolers. *Journal of Sport and Health Science, 9*(6), 657-663.

509. Stephens, R. L. X., Ye Lesesne, Catherine A. Dunn, Lillian Kakietek, Jakub Jernigan, Jan Khan, Laura Kettel. (2014, 2014). Relationship between child care centers' compliance with physical activity regulations and children's physical activity, new york city, 2010. *Preventing Chronic Disease, 11*, E179-E179.

510. Stone, M. R., Houser, N. E., Cawley, J., Kolen, A. M., Rainham, D., Rehman, L., Turner, J., & Kirk, S. F. L. (2019, 2019). Accelerometry-measured physical activity and sedentary behaviour of preschoolers in nova scotia, canada. *Applied Physiology Nutrition and Metabolism, 44*(9), 1005-1011.

511. Stone, N. O., J. Dillenburg, R. Milenkovic, J. MacDonald, M. J. Timmons, B. W. (2015, 2015). Objectively measured physical activity levels of young children with congenital heart disease. *Cardiology in the Young, 25*(3), 520-525.

512. Storli, R. H., T. L. (2010, 2010). Affordances in outdoor environments and children's physically active play in pre-school. *European Early Childhood Education Research Journal, 18*(4), 445-456. https://doi.org/10.1080/1350293X.2010.525923

513. Stough, C. O. M., Mary Beth Robson, Shannon L. Bolling, Christopher Filigno, Stephanie Spear Kichler, Jessica C. Zion, Cynthia Clifford, Lisa M. Simon, Stacey L. Ittenbach, Richard F. Stark, Lori J. (2018, 2018). Are preschoolers meeting the mark? Comparing the dietary, activity, and sleep behaviors of preschoolers with obesity to national recommendations. *Journal of Pediatric Psychology, 43*(4), 452-463. https://doi.org/10.1093/jpepsy/jsx130

514. Sugiyama, T. O., Anthony D. Masters, Jane M. Moore, Gary T. (2012, 2012). Attributes of child care centers and outdoor play areas associated with preschoolers' physical activity and sedentary behavior. *Environment and Behavior, 44*(3), 334-349. https://doi.org/10.1177/0013916510393276

515. Sundberg, F. F. e., G. Fasth, A. Ekelund, U. Sundberg, F. Fors er, G. Fasth, A. Ekelund, U. (2012, 2012). Children younger than 7 years with type 1 diabetes are less physically active than healthy controls. *Acta Paediatrica, 101*(11), 1164-1169. https://doi.org/10.1111/j.1651-2227.2012.02803.x

516. Tan, S. Y. P., B. K. Chong, H. X. Ismail, M. N. Rahman, J. Zarina, A. L. Juraida, A. R. Tahir, A. Ruzita, A. T. Roslee, R. Shanita, S. N. Hamidah, A. Shah, M. I. Norimah, A. K. (2013, 2013). Physical activity of pediatric patients with acute leukemia undergoing induction or consolidation chemotherapy. *Leukemia Research, 37*(1), 14-20.

517. Tanaka, C. H., Yuki Ohkawara, Kazunori Tanaka, Shigeho. (2012, 2012). Locomotive and non-locomotive activity as determined by triaxial accelerometry and physical fitness in japanese preschool children. *Pediatric Exercise Science, 24*(3), 420-434. https://doi.org/10.1123/pes.24.3.420

518. Tanaka, C. T., S. (2009, 2009). Daily physical activity in japanese preschool children evaluated by triaxial accelerometry: The relationship between period of engagement in moderate-to-vigorous physical activity and daily step counts. *Journal of Physiological Anthropology, 28*(6), 283-288.

519. Tanaka, C. T., S. (2013, 2013). Objectively-measured physical activity and body weight in japanese pre-schoolers. *Annals of Human Biology, 40*(6), 541-546.

520. Tandon, P. S., Downing, K. L., Saelens, B. E., & Christakis, D. A. (2019, 2019). Two approaches to increase physical activity for preschool children in child care centers: A matched-pair cluster-randomized trial. *International journal of environmental research and public health, 16*(20).

521. Tandon, P. S. S., Brian E. Zhou, Chuan Kerr, Jacqueline Christakis, Dimitri A. (2013, 2013). Indoor versus outdoor time in preschoolers at child care. *American Journal of Preventive Medicine, 44*(1), 85-88. https://doi.org/10.1016/j.amepre.2012.09.052

522. Tandon, P. S. S., B. E. Christakis, D. A. (2015, 2015). Active play opportunities at child care. *Pediatrics, 135*(6), e1425-1431. https://doi.org/10.1542/peds.2014-2750

523. Tandon, P. S. S., B. E. Copel , K. A. (2017, 2017). A comparison of parent and childcare provider's attitudes and perceptions about preschoolers' physical activity and outdoor time. *Child: Care, Health & Development, 43*(5), 679-686. https://doi.org/10.1111/cch.12429

524. Tandon, P. S. S., B. E. Zhou, Chuan Christakis, D. A. (2018, 2018). A comparison of preschoolers' physical activity indoors versus outdoors at child care. *International journal of environmental research and public health, 15*(11), 2463. https://doi.org/10.3390/ijerph15112463

525. Tarp, J. C., A. White, T. Westgate, K. Bugge, A. Grontved, A. Wedderkopp, N. Andersen, L. B. Cardon, G. Davey, R. Janz, K. F. Kriemler, S. Northstone, K. Page, A. S. Puder, J. J. Reilly, J. J. Sardinha, L. B. van Sluijs, E. M. F. Ekelund, U. Wijndaele, K. Brage, S. International Children's Accelerometry Database, Collaborators. (2018, 2018). Physical activity intensity, bout-duration, and cardiometabolic risk markers in children and adolescents. *International Journal of Obesity, 42*(9), 1639-1650.

526. Tatsumi, Y. M., I. Shimizu, S. Tachibana, M. Ohno, Y. Taniike, M. (2015, 2015). Daytime physical activity and sleep in pre-schoolers with developmental disorders. *Journal of Paediatrics & Child Health, 51*(4), 396-402. https://doi.org/10.1111/jpc.12725

527. Taylor, R. W. C., Adell Knight, Lee Brown, Deirdre A. Meredith-Jones, Kim Haszard, Jillian J. Dawson, Anna M. Taylor, Barry J. Williams, Sheila M. (2015, 2015). A tailored family-based obesity intervention: A randomized trial. *Pediatrics, 136*(2), 282-289. https://doi.org/10.1542/peds.2015-0595

528. Taylor, R. W. G., Andrew R. Heath, Anne-Louise M. Gall , Barbara C. Lawrence, Julie Sayers, Rachel Healey, Dione Tannock, Gerald W. Meredith-Jones, Kim A. Hanna, Maha Hatch, Burt Taylor, Barry J. (2018, 2018). Sleep, nutrition, and physical activity interventions to prevent obesity in infancy: Follow-up of the prevention of overweight in infancy (poi) randomized controlled trial at ages 3.5 and 5 y. *American Journal of Clinical Nutrition, 108*(1), 228-236. https://doi.org/10.1093/ajcn/nqy090

529. Taylor, R. W. H., J. J. Meredith-Jones, K. A. Gall , B. C. Heath, A. M. Lawrence, J. Gray, A. R. Sayers, R. Hanna, M. Taylor, B. J. (2018, 2018). 24-h movement behaviors from infancy to preschool: Cross-sectional and longitudinal relationships with body composition and bone health. *International Journal of Behavioral Nutrition & Physical Activity, 15*(1), 118. https://doi.org/10.1186/s12966-018-0753-6

530. Taylor, R. W. M., L. Carter, P. Gerrard, D. F. Williams, S. M. Taylor, B. J. (2009, 2009). Longitudinal study of physical activity and inactivity in preschoolers: The flame study. *Medicine & Science in Sports & Exercise, 41*(1), 96-102. https://doi.org/10.1249/MSS.0b013e3181849d81

531. Taylor, R. W. W., S. M. Carter, P. J. Goulding, A. Gerrard, D. F. Taylor, B. J. (2011, 2011). Changes in fat mass and fat-free mass during the adiposity rebound: Flame study. *International Journal of Pediatric Obesity, 6*(2), e243-251. https://doi.org/10.3109/17477166.2010.549488

532. Taylor, R. W. W., S. M. Farmer, V. L. Taylor, B. J. (2013, 2013). Changes in physical activity over time in young children: A longitudinal study using accelerometers. *PLoS One, 8*(11), e81567.

533. Taylor, R. W. W., S. M. Dawson, A. M. Haszard, J. J. Brown, D. A. (2015, 2015). Parental motivation to change body weight in young overweight children. *Public Health Nutrition, 18*(10), 1807-1814.

534. Taylor, R. W. W., S. M. Farmer, V. L. Taylor, B. J. (2015, 2015). The stability of sleep patterns in children 3 to 7 years of age. *Journal of Pediatrics, 166*(3), 697-702.e691.

535. Telford, R. M., Olive, L. S., & Telford, R. D. (2021, 2021). A peer coach intervention in childcare centres enhances early childhood physical activity: The active early learning (ael) cluster randomised controlled trial. *The International Journal of Behavioral Nutrition and Physical Activity, 18*(1), 37.

536. Temple, V. A. N., P. J. Rhodes, R. E. Higgins, J. W. (2009, 2009). Physical activity of children in family child care. *Applied Physiology, Nutrition, & Metabolism = Physiologie Appliquee, Nutrition et Metabolisme, 34*(4), 794-798. https://doi.org/10.1139/H09-061

537. Terron-Perez, M. Q., A. Molina-Garcia, J. Martinez-Bello, V. E. (2019, May). Ecological correlates of spanish preschoolers' physical activity during school recess. *European Physical Education Review, 25*(2), 409-423. https://doi.org/10.1177/1356336X17741577

538. Thomas, S., May, T., Barnett, L. M., Papadopoulos, N., McGillivray, J., & Rinehart, N. (2020, 2020). Ecological correlates of sedentary behavior in young children with autism spectrum disorder. *Research in Autism Spectrum Disorders, 78*.

539. Thomas, S. H., T. Barnett, L. M. May, T. Rinehart, N. (2019, Aug). Young children with asd participate in the same level of physical activity as children without asd: Implications for early intervention to maintain good health. *Journal of Autism and Developmental Disorders, 49*(8), 3278-3289.

540. Thompson, A. A., Duckham, R. L., Desai, M. M., Choy, C. C., Sherar, L. B., Naseri, T., Soti-Ulberg, C., Reupena, M. S., Wetzel, A. I., & Hawley, N. L. (2020, 2020). Sex differences in the associations of physical activity and macronutrient intake with child body composition: A cross-sectional study of 3- to 7-year-olds in samoa. *Pediatric Obesity, 15*(4), e12603.

541. Timperio, A. C., David Ball, Kylie Salmon, Jo. (2017, 2017). Typologies of neighbourhood environments and children's physical activity, sedentary time and television viewing. *Health & Place, 43*, 121-127. https://doi.org/10.1016/j.healthplace.2016.10.004

542. Tomaz, S. A., Hinkley, T., Jones, R. A., Twine, R., Kahn, K., Norris, S. A., & Draper, C. E. (2020, 2020). Objectively measured physical activity in south african children attending preschool and grade r: Volume, patterns, and meeting guidelines. *Pediatric Exercise Science, 32*(3), 150-156.

543. Tomaz, S. A. P., A. Watson, E. D. McVeigh, J. A. Rae, D. E. Jones, R. A. Draper, C. E. (2019, 2019). Body mass index, physical activity, sedentary behavior, sleep, and gross motor skill proficiency in preschool children from a low- to middle-income urban setting. *Journal of Physical Activity & Health, 16*(7), 525-532. https://doi.org/10.1123/jpah.2018-0133

544. Tompkins, C. L., Shoulberg, E. K., Meyer, L. E., Martin, C. P., Dennis, M., Krasner, A., & Hoza, B. (2019, 2019). Distinct methods for assessing compliance with a physical activity guideline for children in preschools. *Journal of Physical Activity & Health, 16*(10), 902-907.

545. Tonge, K., Jones, R. A., & Okely, A. D. (2020, 2020). Environmental influences on children's physical activity in early childhood education and care. *Journal of Physical Activity & Health, 17*(4), 423-428.

546. Tsuda, E., Goodway, J. D., Famelia, R., & Brian, A. (2020, 2020). Relationship between fundamental motor skill competence, perceived physical competence and free-play physical activity in children. *Research Quarterly for Exercise & Sport, 91*(1), 55-63.

547. Tucker, P. e., Leigh M. Burke, Shauna M. Irwin, Jennifer D. Johnson, Andrew M. (2015, 2015). Prevalence and influences of preschoolers' sedentary behaviors in early learning centers: A cross-sectional study. *BMC Pediatrics, 15*(1), 1-9. https://doi.org/10.1186/s12887-015-0441-5

548. Tucker, P. e., Leigh M. Johnson, Andrew M. Burke, Shauna M. Irwin, Jennifer D. Gaston, Anca Driediger, Molly Timmons, Brian W. (2017, 2017). Impact of the supporting physical activity in the childcare environment (space) intervention on preschoolers' physical activity levels and sedentary time: A single-blind cluster randomized controlled trial. *International Journal of Behavioral Nutrition & Physical Activity, 14*(1), 1-11. https://doi.org/10.1186/s12966-017-0579-7

549. Tucker, P. M., Alana M. Burke, Shauna M. erloo, Leigh M. Irwin, Jennifer D. (2016, 2016). Comparing physical activity and sedentary time among overweight and nonoverweight preschoolers enrolled in early learning programs: A cross-sectional study. *Applied Physiology, Nutrition & Metabolism, 41*(9), 971-976. https://doi.org/10.1139/apnm-2016-0021

550. Tuominen, P. P. H., P. Raitanen, J. Luoto, R. M. (2016, 2016). Differences in sedentary time and physical activity among mothers and children using a movement-to-music video program in the home environment: A pilot study. *Springerplus, 5*, 93.

551. Turer, C. B. S., M. Brouwer, R. J. Krause, K. M. Lovelady, C. A. Bastian, L. A. Peterson, B. Ostbye, T. (2013, 2013). Do high-risk preschoolers or overweight mothers meet aap-recommended behavioral goals for reducing obesity? *Academic pediatrics, 13*(3), 243-250.

552. Vaipuna, T. F. W. W., S. M. Farmer, V. L. Meredith-Jones, K. A. Richards, R. Gall , B. C. Te Morenga, L. Taylor, R. W. (2018, 2018). Sleep patterns in children differ by ethnicity: Cross-sectional and longitudinal analyses using actigraphy. *Sleep Health, 4*(1), 81-86.

553. Vale, S., & Mota, J. (2020, 2020). Adherence to 24-hour movement guidelines among portuguese preschool children: The prestyle study. *Journal of Sports Sciences, 38*(18), 2149-2154.

554. Vale, S., Santos, R., Silva, P., Soares-Miranda, L., & Mota, J. (2009, 2009). Preschool children physical activity measurement: Importance of epoch length choice. *Pediatric Exercise Science, 21*(4), 413-420. https://doi.org/10.1123/pes.21.4.413

555. Vale, S. M. C. G. S., R. M. R. Soares-Mir a, L. M. da C. Moreira, C. M. M. Ruiz, J. R. Mota, J. A. S. (2010, 2010). Objectively measured physical activity and body mass index in preschool children. *International Journal of Pediatrics, 2010*, Article ID 479439. https://doi.org/10.1155/2010/479439

556. Vale, S. R., N. Soares-Mir a, L. Santos, R. Moreira, C. Mota, J. (2014, 2014). Parental education and physical activity in pre-school children. *Child: Care, Health & Development, 40*(3), 446-452. https://doi.org/10.1111/cch.12041

557. Vale, S. S., Pedro Santos, Rute Soares-Mir a, Luisa Mota, Jorge. (2010, 2010). Compliance with physical activity guidelines in preschool children. *Journal of Sports Sciences, 28*(6), 603-608.

558. Vale, S. S., R. Silva, P. Soares-Mir a, L. Mota, J. (2011, 2011). Relationship of objective measurement of physical activity during school hours and bmi in preschool children. *International Journal of Pediatric Obesity, 6*, 37-38.

559. Vale, S. S., R. Soares-Mir a, L. Silva, P. Mota, J. (2011, 2011). The importance of physical education classes in pre-school children. *Journal of Paediatrics & Child Health, 47*(1), 48-53. https://doi.org/10.1111/j.1440-1754.2010.01890.x

560. Vale, S. T., S. Ruiz, J. J. Rego, C. Moreira, P. Mota, J. (2013, 2013). Physical activity guidelines and preschooler's obesity status. *International Journal of Obesity, 37*(10), 1352-1355.

561. Vale, S. T., S. G. Rego, C. Abreu, S. Mota, J. (2015, 2015). Physical activity, obesity status, and blood pressure in preschool children. *Journal of Pediatrics, 167*(1), 98-102.

562. Vale, S. T., Stewart G. Duncan, Michael J. Mota, Jorge. (2015, 2015). Step based physical activity guidelines for preschool-aged children. *Preventive Medicine, 70*, 78-82.

563. van Assema, P. B., Nina H. M. Kremers, Stef P. J. Jansen, Maria W. J. Savelberg, Hans H. C. M. Oosterhoff, Marije Willeboordse, Maartje van Schayck, Onno C. P. Winkens, Bjorn. (2019, 2019). One- and two-year effects of the healthy primary school of the future on children's dietary and physical activity behaviours: A quasi-experimental study. *Nutrients, 11*(3), 689-689. https://doi.org/10.3390/nu11030689

564. van Bakergem, M. S., Evan C. Heerman, William J. Hipp, James Aaron Barkin, Shari L. (2017, 2017). Objective reports versus subjective perceptions of crime and their relationships to accelerometer-measured physical activity in hispanic caretaker-child dyads. *Preventive Medicine, 95*, S68-S74.

565. Van Cauwenberg, E. L., V. Gubbels, J. De Bourdeaudhuij, I. Cardon, G. (2012, Jun). Preschooler's physical activity levels and associations with lesson context, teacher's behavior, and environment during preschool physical education. *Early Childhood Research Quarterly, 27*(2), 221-230. https://doi.org/10.1016/j.ecresq.2011.09.007

566. Van Cauwenberghe, E. D. B., I. Maes, L. Cardon, G. (2012, 2012). Efficacy and feasibility of lowering playground density to promote physical activity and to discourage sedentary time during recess at preschool: A pilot study. *Preventive Medicine, 55*(4), 319-321.

567. Van Cauwenberghe, E. D. C., Marieke De Decker, Ellen De Bourdeaudhuij, Ilse Cardon, Greet. (2013, 2013). The impact of a teacher-led structured physical activity session on preschoolers' sedentary and physical activity levels. *Journal of Science & Medicine in Sport, 16*(5), 422-426. https://doi.org/10.1016/j.jsams.2012.11.883

568. Van Cauwenberghe, E. G., J. De Bourdeaudhuij, I. Cardon, G. (2011, 2011). Feasibility and validity of accelerometer measurements to assess physical activity in toddlers. *International Journal of Behavioral Nutrition & Physical Activity, 8*, 67. https://doi.org/10.1186/1479-5868-8-67

569. Van Cauwenberghe, E. J., R. A. Hinkley, T. Crawford, D. Okely, A. D. (2012, 2012). Patterns of physical activity and sedentary behaviour in preschool children. *International Journal of Behavioral Nutrition & Physical Activity, 9*, 138. https://doi.org/10.1186/1479-5868-9-138

570. Van Cauwenberghe, E. W., L. Mackay, L. Cardon, G. Oliver, M. Van Cauwenberghe, Eveline Wooller, Leslie Mackay, Lisa Cardon, Greet Oliver, Melody. (2012, 2012). Comparison of actical and activpal measures of sedentary behaviour in preschool children. *Journal of Science & Medicine in Sport, 15*(6), 526-531. https://doi.org/10.1016/j.jsams.2012.03.014

571. van de Kolk, I., Gerards, S., Harms, L. S. E., Kremers, S. P. J., & Gubbels, J. S. (2019, 2019). The effects of a comprehensive, integrated obesity prevention intervention approach (superfit) on children's physical activity, sedentary behavior, and bmi z-score. *International journal of environmental research and public health, 16*(24).

572. van Ekris, E., Wijndaele, K., Altenburg, T. M., Atkin, A. J., Twisk, J., Andersen, L. B., Janz, K. F., Froberg, K., Northstone, K., Page, A. S., Sardinha, L. B., van Sluijs, E. M. F., Chinapaw, M., On behalf of the International Children's Accelerometry Database, C., Andersen, L. B., Anderssen, S., Atkin, A. J., Cardon, G., Davey, R., & Ekelund, U. (2020, 2020). Tracking of total sedentary time and sedentary patterns in youth: A pooled analysis using the international children's accelerometry database (icad). *International Journal of Behavioral Nutrition & Physical Activity, 17*(1), 1-10.

573. van Ekris, E. S.-M., E. Chinapaw, M. J. M. Jago, R. Altenburg, T. M. (2018, 2018). Child- and parent-related correlates of total and prolonged sedentary time in 5- to 6-year-old children. *International Journal of Environmental Research & Public Health [Electronic Resource], 15*(9), 22.

574. van Leeuwen, J., Koes, B. W., Paulis, W. D., Bindels, P. J. E., & van Middelkoop, M. (2020, 2020). No differences in physical activity between children with overweight and children of normal-weight. *BMC Pediatrics, 20*(1), 1-7.

575. van Sluijs, E. M. M., A. M. Inskip, H. M. Ekelund, U. Godfrey, K. M. Harvey, N. C. Griffin, S. J. (2013, 2013). Correlates of light and moderate-to-vigorous objectively measured physical activity in four-year-old children. *PLoS ONE [Electronic Resource], 8*(9), e74934. https://doi.org/10.1371/journal.pone.0074934

576. Vanderloo, L. M. D. C., Natascja A. Proudfoot, Nicole A. Tucker, Patricia Timmons, Brian W. (2016, 2016). Comparing the actical and actigraph approach to measuring young children's physical activity levels and sedentary time. *Pediatric Exercise Science, 28*(1), 133-142. https://doi.org/10.1123/pes.2014-0218

577. Vanderloo, L. M. T., P. Johnson, A. M. Holmes, J. D. (2013, 2013). Physical activity among preschoolers during indoor and outdoor childcare play periods. *Applied Physiology, Nutrition and Metabolism, 38*(11), 1173-1175. https://doi.org/10.1139/apnm-2013-0137

578. Vanderloo, L. M. T., P. Johnson, A. M. voort, M. M. van Burke, S. M. Irwin, J. D. (2014, 2014). The influence of centre-based childcare on preschoolers' physical activity levels: A cross-sectional study. *International journal of environmental research and public health, 11*(2), 1794-1802. https://doi.org/10.3390/ijerph110201794

579. Vanderloo, L. M. T., P. (2015, 2015). Weekly trends in preschoolers' physical activity and sedentary time in childcare. *International Journal of Environmental Research & Public Health [Electronic Resource], 12*(3), 2454-2464.

580. Vanderloo, L. M. T., Patricia. (2015, 2015). An objective assessment of toddlers' physical activity and sedentary levels: A cross-sectional study. *BMC Public Health, 15*(1), 1-10. https://doi.org/10.1186/s12889-015-2335-8

581. Vanderloo, L. M. T., Patricia Johnson, Andrew M. Burke, Shauna M. Irwin, Jennifer D. (2015, 2015). Environmental influences on preschoolers' physical activity levels in various early-learning facilities. *Research Quarterly for Exercise & Sport, 86*(4), 360-370. https://doi.org/10.1080/02701367.2015.1053105

582. Vanderloo, L. M. T., Patricia. (2017, 2017). Physical activity and sedentary time among young children in full-day kindergarten: Comparing traditional and balanced day schedules. *Health Education Journal, 76*(1), 29-37. https://doi.org/10.1177/0017896916643354

583. Vaughn, A. E. H., Derek Ward, Dianne S. (2013, 2013). Measuring the physical activity practices used by parents of preschool children. *Medicine & Science in Sports & Exercise, 45*(12), 2369-2377. https://doi.org/10.1249/MSS.0b013e31829d27de

584. Veitch, J. T., A. Crawford, D. Abbott, G. Giles-Corti, B. Salmon, J. (2011, Jun). Is the neighbourhood environment associated with sedentary behaviour outside of school hours among children? *Annals of Behavioral Medicine, 41*(3), 333-341.

585. Veldman, S. L. C. J., R. A. Santos, R. Sousa-Sa, E. Pereira, J. R. Zhang, Z. Okely, A. D. (2018, 2018). Associations between gross motor skills and physical activity in australian toddlers. *Journal of Science & Medicine in Sport, 21*(8), 817-821. https://doi.org/10.1016/j.jsams.2017.12.007

586. Veldman, S. L. C. S., Rebecca M. Okely, Anthony D. Jones, Rachel A. (2018, 2018). The association between staff intention and pre-schoolers’ physical activity in early childhood education and care services. *Early Child Development and Care*, No Pagination Specified-No Pagination Specified. https://doi.org/10.1080/03004430.2018.1555824

587. Verbestel, V. D. H., S. Bammann, K. Barba, G. Hadjigeorgiou, C. Eiben, G. Konstabel, K. Kovacs, E. Pitsiladis, Y. Reisch, L. Santaliestra-Pasias, A. M. Maes, L. De Bourdeaudhuij, I. Consortium, Idefics. (2015, 2015). Are context-specific measures of parental-reported physical activity and sedentary behaviour associated with accelerometer data in 2-9-year-old european children? *Public Health Nutrition, 18*(5), 860-868.

588. Verbestel, V. D. H., S. Barba, G. Eiben, G. Gallois, K. Hadjigeorgiou, C. Konstabel, K. Maes, L. Marild, S. Molnar, D. Moreno, L. A. Oja, L. Pitsiladis, Y. Ahrens, W. Pigeot, I. De Bourdeaudhuij, I. consortium, Idefics. (2015, 2015). Effectiveness of the idefics intervention on objectively measured physical activity and sedentary time in european children. *Obesity Reviews, 16*, 57-67. https://doi.org/10.1111/obr.12348

589. Verbestel, V. V. C., Eveline De Coen, Valerie Maes, Lea De Bourdeaudhuij, Ilse Cardon, Greet. (2011, 2011). Within-- and between-day variability of objectively measured physical activity in preschoolers. *Pediatric Exercise Science, 23*(3), 366-378. https://doi.org/10.1123/pes.23.3.366

590. Verloigne, M. A., W. De Henauw, S. Verbestel, V. Marild, S. Pigeot, I. De Bourdeaudhuij, I. consortium, Idefics. (2015, 2015). Process evaluation of the idefics school intervention: Putting the evaluation of the effect on children's objectively measured physical activity and sedentary time in context. *Obesity Reviews, 16*, 89-102. https://doi.org/10.1111/obr.12353

591. Verswijveren, S. J. J. M., Wiebe, S. A., Rahman, A. A., Kuzik, N., & Carson, V. (2020, 2020). Longitudinal associations of sedentary time and physical activity duration and patterns with cognitive development in early childhood. *Mental Health and Physical Activity, 19*.

592. Vinke, P. C., Tigelaar, C., Kupers, L. K., & Corpeleijn, E. (2021, 2021). The role of children's dietary pattern and physical activity in the association between breastfeeding and bmi at age 5: The gecko drenthe cohort. *Maternal and child health journal, 25*(2), 338-348.

593. Vorwerg, Y. P., D. Kiess, W. Bluher, S. (2013, 2013). Physical activity in 3-6 year old children measured by sensewear pro: Direct accelerometry in the course of the week and relation to weight status, media consumption, and socioeconomic factors. *PLoS ONE [Electronic Resource], 8*(4), e60619. https://doi.org/10.1371/journal.pone.0060619

594. Walsh, A. D. C., David Cameron, Adrian J. Campbell, Karen J. Hesketh, Kylie D. (2017, 2017). Associations between the physical activity levels of fathers and their children at 20 months, 3.5 and five years of age. *BMC Public Health, 17*, 1-8. https://doi.org/10.1186/s12889-017-4545-8

595. Wang, Y. C. C., Li-Chiou Tung, Yi-Ching Lee, Chien-Chang Tsai, Shao-Yu. (2019, 2019). Physical activity and objectively assessed sleep in 6-month-old infants in taiwan. *Research in Nursing & Health, 42*(2), 128-135. https://doi.org/10.1002/nur.21929

596. Ward, D. S., Vaughn, A. E., Burney, R. V., Hales, D., Benjamin-Neelon, S. E., Tovar, A., & Østbye, T. (2020, 2020). Keys to healthy family child care homes: Results from a cluster randomized trial. *Preventive Medicine, 132*, N.PAG-N.PAG.

597. Ward, S. B., M. Donovan, D. Vatanparast, H. Muhajarine, N. Engler-Stringer, R. Leis, A. Humbert, M. L. Carrier, N. (2017, 2017). Association between childcare educators' practices and preschoolers' physical activity and dietary intake: A cross-sectional analysis. *BMJ Open, 7*(5), e013657.

598. Ward, S. B., Mathieu Donovan, Denise Boudreau, Jonathan Vatanparast, Hassan Muhajarine, Nazeem Leis, Anne Humbert, M. Louise Carrier, Natalie. (2017, 2017). "Monkey see, monkey do": Peers' behaviors predict preschoolers' physical activity and dietary intake in childcare centers. *Preventive Medicine, 97*, 33-39.

599. Wasenius, N. S. G., K. P. Harvey, A. L. J. Barrowman, N. Goldfield, G. S. Adamo, K. B. (2017, 2017). Maternal gestational weight gain and objectively measured physical activity among offspring. *PLoS ONE [Electronic Resource], 12*(6), e0180249. https://doi.org/10.1371/journal.pone.0180249

600. Webster, E. K., Robinson, L. E., & Wadsworth, D. D. (2020, 2020). Factors that influence participation in classroom-based physical activity breaks in head start preschoolers. *Journal of Physical Activity & Health, 17*(2), 162-168.

601. Webster, E. K. M., C. K. Staiano, A. E. (2019, Mar). Fundamental motor skills, screen-time, and physical activity in preschoolers. *Journal of Sport and Health Science, 8*(2), 114-121.

602. Webster, E. K. W., Danielle D. Robinson, Leah E. (2015, 2015). Preschoolers’ time on-task and physical activity during a classroom activity break. *Pediatric Exercise Science, 27*(1), 160-167. https://doi.org/10.1123/pes.2014-0006

603. Weimann, H. B., J. Ryl er, L. Bergman, P. Eiben, G. (2015, 2015). Neighborhood environment and physical activity among young children: A cross-sectional study from sweden. *Scandinavian Journal of Public Health, 43*(3), 283-293.

604. Wen, L. M. v. d. P., H. P. Kite, J. Cashmore, A. Rissel, C. (2010, 2010). A validation study of assessing physical activity and sedentary behavior in children aged 3 to 5 years. *Pediatric Exercise Science, 22*(3), 408-420. https://doi.org/10.1123/pes.22.3.408

605. Wiersma, R., Hartman, E., Boezen, H. M., & Corpeleijn, E. (2020, 2020). Adiposity and high blood pressure during childhood: A prospective analysis of the role of physical activity intensity and sedentary time in the gecko drenthe cohort. *International journal of environmental research and public health, 17*(24).

606. Wiersma, R., Lu, C. C., Hartman, E., & Corpeleijn, E. (2019, 2019). Physical activity around the clock: Objectively measured activity patterns in young children of the gecko drenthe cohort. *BMC Public Health, 19*(1).

607. Wijndaele, K., White, T., Andersen, L. B., Bugge, A., Kolle, E., Northstone, K., Wedderkopp, N., Ried-Larsen, M., Kriemler, S., Page, A. S., Puder, J. J., Reilly, J. J., Sardinha, L. B., van Sluijs, E. M. F., Sharp, S. J., Brage, S., Ekelund, U., Andersen, L. B., Atkin, A. J., Cardon, G., Davey, R., Ekelund, U., Esliger, D. W., Hallal, P., Hansen, B. H., Janz, K. F., Kriemler, S., Moller, N., Northstone, K., Page, A., Pate, R., Puder, J. J., Reilly, J. J., Salmon, J., Sardinha, L. B., Sherar, L. B., Timperio, A., van Sluijs, E. M. F., & Int Childrens, A. (2019, 2019). Substituting prolonged sedentary time and cardiovascular risk in children and youth: A meta-analysis within the international children's accelerometry database (icad). *International Journal of Behavioral Nutrition and Physical Activity, 16*(1).

608. Wijtzes, A. I. K., M. N. Kiefte-de Jong, J. C. de Vries, S. I. Henrichs, J. Jansen, W. Jaddoe, V. W. Hofman, A. Moll, H. A. Raat, H. (2013, 2013). Correlates of physical activity in 2-year-old toddlers: The generation r study. *Journal of Pediatrics, 163*(3), 791-799.e791-792.

609. Williams, S. M. F., V. L. Taylor, B. J. Taylor, R. W. (2014, 2014). Do more active children sleep more? A repeated cross-sectional analysis using accelerometry. *PLoS ONE [Electronic Resource], 9*(4), e93117. https://doi.org/10.1371/journal.pone.0093117

610. Williamson, M. L. B., Jacob. (2013). *The difference in physical activity levels and attention in preschool children before and after free play recess and structured play recess* (Publication Number 3618843) Kent State University]. Ann Arbor.

611. Willoughby, M. T. W., Am a C. Catellier, Diane J. (2018, 2018). Testing the association between physical activity and executive function skills in early childhood. *Early Childhood Research Quarterly, 44*, 82-89. https://doi.org/10.1016/j.ecresq.2018.03.004

612. Wolfenden, L. J., Jannah Parmenter, Ben Razak, Lubna Abdul Wiggers, John Morgan, Philip J. Finch, Meghan Sutherl , Rachel Lecathelinais, Christophe Clinton-McHarg, Tara Gillham, Karen Yoong, Sze Lin. (2019, 2019). Efficacy of a free-play intervention to increase physical activity during childcare: A randomized controlled trial. *Health Education Research, 34*(1), 84-97.

613. Wong, S., Cantoral, A., Tellez-Rojo, M. M., Pantic, I., Oken, E., Svensson, K., Dorman, M., Gutierrez-Avila, I., Rush, J., McRae, N., Wright, R. O., Baccarelli, A. A., Kloog, I., & Just, A. C. (2020, 2020). Associations between daily ambient temperature and sedentary time among children 4-6 years old in mexico city. *PLoS One, 15*(10), e0241446.

614. Wosje, K. S. K., P. R. Claytor, R. P. Copel , K. A. Kalkwarf, H. J. Daniels, S. R. Wosje, Karen S. Khoury, Philip R. Claytor, R al P. Copel , Kristen A. Kalkwarf, Heidi J. Daniels, Stephen R. (2009, 2009). Adiposity and tv viewing are related to less bone accrual in young children. *Journal of Pediatrics, 154*(1), 79-85.e72.

615. Wosje, K. S. K., P. R. Claytor, R. P. Copel , K. A. Hornung, R. W. Daniels, S. R. Kalkwarf, H. J. (2010, 2010). Dietary patterns associated with fat and bone mass in young children. *American Journal of Clinical Nutrition, 92*(2), 294-303.

616. Wyszynska, J., Matlosz, P., Asif, M., Szybisty, A., Lenik, P., Deren, K., Mazur, A., & Herbert, J. (2021, 2021). Association between objectively measured body composition, sleep parameters and physical activity in preschool children: A cross-sectional study. *BMJ Open, 11*(1).

617. Wyszynska, J., Matlosz, P., Szybisty, A., Deren, K., Mazur, A., & Herbert, J. (2021, 2021). The association of actigraphic sleep measures and physical activity with excess weight and adiposity in kindergarteners. *Scientific Reports, 11*(1), 2298.

618. Wyszynska, J., Matlosz, P., Szybisty, A., Lenik, P., Deren, K., Mazur, A., & Herbert, J. (2020, 2020). Obesity and body composition in preschool children with different levels of actigraphy-derived physical activity-a cross-sectional study. *Journal of Clinical Medicine, 9*(4).

619. Xu, C. Q., M. Zhang, H. Zhou, C. Chen, P. (2018, 2018). Impact of parents' physical activity on preschool children's physical activity: A cross-sectional study. *PeerJ, 6*, e4405.

620. Yamamoto, S. B., S. Fischer, J. De Bock, F. (2011, Feb). Sex differences in the variables associated with objectively measured moderate-to-vigorous physical activity in preschoolers. *Preventive Medicine, 52*(2), 126-129.

621. Yoong, S. L. G., A. Stacey, F. Polimeni, M. Clayton, O. Jones, J. Nathan, N. Wyse, R. Wolfenden, L. (2019, 2019). A pilot randomized controlled trial examining the impact of a sleep intervention targeting home routines on young children's (3-6 years) physical activity. *Pediatric Obesity, 14*(4), e12481. https://doi.org/10.1111/ijpo.12481

622. Zeng, N. (2021). *Relationships among physical activity, motor skill competence, cardiovascular fitness, perceived competence, and cognition in preschool children* ProQuest Information & Learning]. US.

623. Zhang, B., Liu, Y., Zhao, M. M., Meng, X. X., Deng, Y. Q., Zheng, X. Y., Wang, X. C., Xiong, S. X., & Han, Y. G. (2020, 2020). Differential effects of acute physical activity on executive function in preschoolers with high and low habitual physical activity levels. *Mental Health and Physical Activity, 18*.

624. Zhang, X., Chen, S., & Gu, X. (2020, 2020). Ethnic disparities in mental health and movement behaviors during childhood: Examining the longitudinal developmental patterns. *Journal of Racial and Ethnic Health Disparities, 7*(6), 1249-1257.

625. Zhang, Z. P., J. R. Sousa-Sa, E. Okely, A. D. Feng, X. Santos, R. (2018, 2018). Environmental characteristics of early childhood education and care, daily movement behaviours and adiposity in toddlers: A multilevel mediation analysis from the get up! Study. *Health & Place, 54*, 236-243. https://doi.org/10.1016/j.healthplace.2018.10.008

626. Zhang, Z. S.-S., E. Pereira, J. Chaput, J. P. Okely, A. Feng, X. Santos, R. (2019, 2019). Correlates of nocturnal sleep duration, nocturnal sleep variability, and nocturnal sleep problems in toddlers: Results from the get up! Study. *Sleep Medicine, 53*, 124-132.