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Physical Activity for Health

Sedentary Behaviour in 3-4 Year Olds: Parental Influences and Associations with Motor Competence

by

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Declaration of authenticity and author's rights

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Declaration of Contribution to Thesis

The majority of the work presented in this thesis is the result of my own efforts, conducted under the guidance of Dr Xanne Janssen and Professor John J Reilly. I was primarily responsible for leading the research activities, performing all statistical analyses, and preparing manuscripts for submission to international journals. My supervisors contributed by advising on study design, offering guidance on statistical approaches, and providing detailed feedback on all written components of the thesis.

One of the studies included in this thesis utilised data from the SUNRISE International Study. The primary data collection for this study was carried out by the SUNRISE research teams in each participating country, following the standardised SUNRISE protocol. The SUNRISE Coordinating Centre supported this project by supplying the data used in the secondary analysis. This work greatly benefited from the support of my supervisors and the collaborative input from the broader SUNRISE International Study network.

All co-authors listed in the associated publications were involved in data collection, offered constructive feedback throughout the manuscript development process, and approved the final published versions. Individual author contributions for each study are detailed below.

- *Chapter 2*

Nana Kwofie: Conceptualisation, Methodology, Investigation, Formal analysis, Visualisation, Writing - original draft preparation.

Dr Xanne Janssen: Conceptualisation, Methodology, Supervision, Writing - review & editing.

Prof. John J Reilly: Conceptualisation, Methodology, Supervision, Writing - review & editing.

- *Chapter 3*

Nana Kwofie: Conceptualisation, Methodology, Investigation, Formal analysis, Visualisation, Writing - original draft preparation.

Dr Xanne Janssen: Conceptualisation, Methodology, Supervision, Writing - review & editing.

Prof. John J Reilly: Conceptualisation, Methodology, Supervision, Writing - review & editing.

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Dr Xanne Janssen: Conceptualisation, Methodology, Supervision, Writing - review & editing.

Prof. John J Reilly: Conceptualisation, Methodology, Supervision, Writing - review & editing.

Dr Andrew Dalziel: Methodology - Lead on qualitative data collection.

Abstract

Introduction

Excessive screen time is becoming increasingly prevalent in the early years, raising concerns about its impact on other movement behaviours (physical activity and sleep) and on health outcomes, including motor competence. Limited evidence exists on how sedentary behaviour influences motor competence in 3-4-year-olds, and little is known about parental perceptions influencing adherence to screen time guidelines. This thesis aimed to address these gaps by examining associations between (a) screen time, habitual sedentary behaviour, and motor competence; (b) screen time, sedentary behaviour, guideline adherence and fine and gross motor skills; and (c) exploring parents' perceived barriers and facilitators to meeting screen time recommendations.

Methods

Three studies were conducted. Study 1 was a systematic review examining associations between screen time, habitual sedentary behaviour, and multiple domains of motor competence, including fundamental, fine, gross, locomotor, object control, and balance in 3-4-year-olds. Study 2 analysed data from the pilot phase of the SUNRISE International Study, comprising 1,394 children aged 3-4 years. Sedentary behaviour was objectively assessed using the activPAL accelerometer, while screen time and restraint were measured via parent questionnaires. Fine and gross motor skills were evaluated using the parent-reported Ages and Stages Questionnaire, Third Edition (ASQ-3). Associations were examined between a) screen time and total daily accelerometery measured sedentary behaviour with gross and fine motor skills; b) meeting overall sedentary behaviour guidelines (restraint and screen time guidelines) and fine and gross motor skills. Using a mixed-methods design, Study 3 explored parental perceptions of adherence to the screen time guideline and examined differences in perceptions between those who meet and those who do not meet the guideline. The quantitative component included an exploratory sample of 56 participants aged 3-4 years, while the qualitative component included a convenience sample of 19 parents of children aged 3-4 years from both high- and low-income settings across Scotland. Screen time was measured using a parent report questionnaire.

Results

Higher screen time and sedentary behaviour were generally associated with poorer motor competence in Studies 1 and 2. The systematic review found predominantly negative associations between screen time and sedentary behaviour and various motor competence domains, suggesting that sedentary behaviour may negatively affect the motor competence of children aged 3-4 years. Study 2 confirmed these findings, showing that higher screen time was significantly associated with lower fine and gross motor skills, and that only 42% of children met the overall sedentary behaviour guidelines. Study 3 also showed that just 40% of children in the sample met the screen time guideline, with parents citing barriers to meeting the guideline, such as busy schedules, poor weather, and health challenges, while highlighting awareness of the guidelines and supportive family structures as key facilitators.

Conclusion

Excessive screen time and sedentary behaviour may negatively influence motor competence in 3-4-year-olds. Low guideline adherence underscores the probable need for family-focused interventions that consider parental, environmental, and behavioural factors to promote healthier screen time and optimal motor competence in 3-4-year-olds.

Acknowledgements

Foremost, I would like to thank God for how far He has brought me on this academic journey -the successful completion of my four-plus years of research. This has been by far the most challenging, demanding and daring journey I have had to make, and I am glad it has ended with so much grace.

To my able supervisors -Dr Xanne Janssen and Prof. John Reilly -under whose tutelage this thesis has become fruitful, I say thank you! I owe you both a debt of gratitude for your guidance, support, and help throughout these challenging years. Your valuable feedback has always been critical in shaping and refining my research writing and ideas, and your immense contribution to this research is appreciated.

To the entire staff of the department of Psychological Sciences and Health, and my colleagues I had the opportunity to cross paths with, thank you for the support, the company, and the light you shed on this journey.

Special thanks to my loving husband, who has been a formidable support system and has kept me sane every step of the way. To my family- mum and siblings- who have been incredibly supportive with their prayers and words of encouragement, I thank you and love you all dearly!

Finally, to all my friends and well-wishers who cheered me on from far and near -we finally made it. THANK YOU.

List of Abbreviations

BMI= Body Mass Index

FMS= Fundamental Movement Skills

GMQ= Gross Motor Quotient

LPA= Light-intensity Physical Activity

MABC-2= Movement Assessment Battery for Children-2

MC= Motor Competence

METs= Metabolic Equivalents

MVPA= Moderate-to-Vigorous Intensity Physical Activity

PRISMA= Preferred Reporting Items for Systematic Reviews and Meta-Analyses

SB= Sedentary Behaviour

SES= Socioeconomic Status

SIMD= Scottish Index of Multiple Deprivation

ST= Screen Time

SUNRISE International= Surveillance Study of Movement Behaviours in the Early Years

WHO= World Health Organization

Glossary Terms

Excessive sedentary behaviour- When the duration and/or context of low-activity states exceeds the guideline recommendation

Light-intensity physical activity - Any bodily movement which requires an exertion that measures between 1.5 and 3.0 METs.

Moderate-intensity physical activity - Any bodily movement which requires an exertion that measures between 3.0 and 6.0 METs.

Motor competence - An individual's degree of proficient performance in a broad range of motor skills, as well as the underlying mechanisms, including quality of movement, motor coordination and motor control.

Screen time - A period of time during which a person uses any screen-based device.

Screen time guideline- For children 3-4-year-olds, not more than 60 minutes a day spent on screen time.

Sedentary behaviour (SB) - Any waking behaviour characterised by an energy expenditure of ≤1.5 METs whilst in a sitting or reclining posture.

Sedentary behaviour guideline - For children 3–4-year-olds, meeting the combination of screen time guideline (not more than 1 hour a day on screen) and restraint guideline (not restrained for more than 1 hour at a time).

Physical activity (PA) - Any bodily movement which requires an exertion that measures above 1.5 METs.

Prevalence - A measure that describes how many people are affected by or have a particular problem in a defined population.

Restraint guideline- For children 3-4-year-olds, not to be restrained for more than an hour at a time (e.g., prams/strollers) or sit for extended periods.

The 24-hour movement guideline - Refers to the amount of time recommended by the WHO, in a 24-hour day, that children under 5 years of age should spend on physical activity, sedentary behaviour, and sleep for their health and wellbeing.

Vigorous-intensity physical activity - Any bodily movement which requires an exertion which measures greater than 6.0 METs.

24hr movement behaviours - Refers to an umbrella concept encompassing the physical behaviours (physical activity, screen time and sleep) that occur along a movement intensity continuum within 24 hours.

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Summary of Publications, Submitted Manuscripts and Presentations

1. *Publications from the thesis*

Chapter 2

Kwofie, N. A., Janssen, X., & Reilly, J. J. (2024). Associations Between Sedentary Behaviour and Motor Competence in 3-to 4-Year-Olds: A Systematic Review. *Journal of Motor Learning and Development*, *1*(aop), 1-23.

Chapter 3

Kwofie, N. A., Suherman, A., Florindo, A. A., Staiano, A., Ha, A. S., Okely, A. D., ... & Janssen, X. (2025). Associations between sedentary behaviour and fine and gross motor skills in 3-to 4-year-olds: a secondary data analysis from Sunrise International Study pilot studies. *Child: Care, Health and Development*, *51*(3), e70092.

2. *Conference presentations from the thesis*

Kwofie, N. A., Janssen, X., & Reilly, J. J. (2024). Associations Between Sedentary Behaviour and Motor Competence in 3-to 4-Year-Olds: A Systematic Review. S*cottish Physical Activity Research Connections Conference, Edinburgh, UK. November 2022.*

Kwofie, N. A., Janssen, X., & Reilly, J. J. (2024). Levels of meeting the 24-hr movement guidelines in 3- to 4-year-olds in Scotland- A pilot study. A Systematic Review. S*cottish Physical Activity Research Connections Conference, Edinburgh, UK. November 2023.*

Kwofie, N. A., Janssen, X., & Reilly, J. J. (2024). Exploring Parents' Perceptions of Screen Time in 3-4 Year Olds. *Lumivero virtual conference, 2024.*

General Introduction and Purpose of the Thesis

The overarching theme of this research is to examine the influence of sedentary behaviour on the health of children aged 3-4 years. The goal is to generate evidence that can inform stakeholders in child health and development on the impact of sedentary behaviour on children. This thesis is divided into five chapters, presented in manuscript and study format, each addressing the effects of screen time on 3-4-year-olds.

Chapter 1: Background and Introduction- This chapter introduces the context of the study, reviews the literature, identifies research gaps and objectives, and provides the rationale and purpose of the thesis.

Chapter 2: Study 1 "The association between screen time and sedentary behaviour and motor competence in 3–4-year-olds: A systematic review". This study examines the association between time spent in different types of sedentary behaviour (screen time and habitual sedentary behaviour) and motor competence (fundamental motor skills, fine and gross motor skills, locomotor skills, object control skills, and balance). This chapter of the thesis is published in the Journal of Motor Learning and Development and presented in its published form.

Chapter 3: Study 2- "Association between sedentary behaviour and fine and gross motor skills in 3-4-year-olds: a secondary data analysis from the SUNRISE international study". This study examines the associations between 1) screen time (hours/day) and total daily SB (hours/day), and gross and fine motor skills; and 2) meeting the restraint, screen time, and overall SB (restraint and screen time) guidelines and fine and gross motor skills. This chapter of the thesis is also published in the Child: Care, Health and Development journal and presented in the published form.

Chapter 4: Study 3- "Sedentary behaviour in 3-4-year-olds in Scotland and parental perceptions of barriers to and facilitators of meeting the screen time guideline: a mixed methods study". The focus of this study is to better understand parents' perceptions of the barriers and facilitators to meeting the

screen time guideline and to examine differences in perception between those who meet and those who do not meet the guideline.

Chapter 5: Discussion- Chapters 1-4 will be followed by a general discussion that identifies the key findings from each study, the strengths and limitations of the overall thesis, and concludes with the implications of this research for public health and future research.

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Chapter 1: Introduction to the Thesis

1.1 Chapter overview

The focus of this thesis is to examine the influence of sedentary behaviour on motor competence in 3-4-year-olds. In this first opening chapter of the thesis, an overview of the background of the movement behaviours -physical activity, sedentary behaviour, and sleep -will be presented, along with definitions of key concepts and terms related to these behaviours. More specifically, in-depth details will be provided on each movement behaviour, the importance of integrating all three movement behaviours rather than individual behaviours in isolation, and the impact of movement behaviours on health and development outcomes. This chapter will also discuss the 24-hour movement guidelines, developed by the World Health Organisation (WHO) through thorough scientific and evidence-based research (WHO, 2019), why adherence to the guidelines matters, and the prevalence of adherence among 3-4-year-olds. This will be followed by a rationale for focusing the thesis on the sedentary behaviour guideline, including meeting both the restraint and screen time recommendations. It will also examine the correlates of screen time using socio-ecological models, the impact of excessive screen time on children's health and developmental outcomes aged 3–4 years, and parents' perceptions of the barriers and facilitators to meeting the screen time guideline. Finally, motor competence as an important health indicator in the early years will be discussed, and how sedentary behaviour is associated with motor competence will be examined in depth, including the importance and influences (i.e., correlates and determinants) of motor competence in 3-4-year-olds. This will lead to the rationale for this thesis, identifying the current gaps in existing research. The aims, objectives and research question for this thesis will then be clearly outlined and explained.

1.2 Key Concepts and Definitions

1.2.1 Physical Activity Concepts and Definition

Physical activity refers to "any bodily movement produced by skeletal muscles that results in energy expenditure" (Casperson et al., 1985) and can include walking, exercising and doing some household chores. Physical activity involves four components -volume, intensity, frequency, and type -which all

contribute to health; however, most guidelines focus on volume, frequency, and intensity (Oberg, 2007). The volume component of physical activity specifies the minimum number of minutes of physical activity individuals should engage in each day. Frequency of physical activity refers to the number of times per day or week an individual participates in physical activity, while intensity is the degree of exertion, often expressed relative to resting energy expenditure as metabolic equivalents (METs; 1 MET equals the energy expended at rest).

1.2.2 Screen Time and Sedentary Behaviour Concepts and Definitions

Screen time - Throughout this thesis, the term screen time refers to a period during which a person uses any screen-based device, including, but not limited to, TVs, laptops, computers, tablets, and smartphones (Downing et al., 2017; Wiberg & Wiberg, 2019). Screen time refers to a non-quantified period during which screen-based devices are used for a specific activity or purpose (Kaye et al., 2020). For this thesis, "excessive screen time" will be interpreted as "time in excess of the screen time guideline". The use of "digital media" in this thesis will refer to screen-based devices that can access and transmit content and information via the internet, such as mobile apps, games, and other websites (Canadian Paediatric Society, 2017; Plowman, 2016). "Screen time guideline," as used in this thesis, refers to the WHO screen time recommendation for 3–4-year-olds of no more than 1 hour a day (WHO, 2019).

Restraint - For this thesis, the term 'restraint' will refer to the WHO movement guideline for under 5s, which recommends that children aged 3-4 years old not be restrained for more than 1 hour at a time (e.g., prams/strollers) or sit for extended periods of time (WHO, 2019).

Sedentary behaviour - "Sedentary behaviour" is defined as any waking behaviour characterised by an energy expenditure ≤1.5 metabolic equivalents while in a sitting, reclining or lying posture (Tremblay et al., 2017). Sedentary behaviour may include smartphone and tablet use, TV viewing, playing video games, and computer use while sitting. Measurement of sedentary behaviour is characterised using frequency, interruptions, time and type principle (Tremblay et al., 2010) and in accordance with sedentary behaviour guidelines. For this thesis, the "sedentary behaviour guideline" refers to the combination of the WHO screen time and restraint guidelines.

1.2.3 Sleep Concept and Definition

Sleep is a physiological state that occurs in alternation with wakefulness, usually defined as a "naturally recurring state of body and mind characterised by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles and reduced interactions with surroundings" (Chaput et al., 2017). Optimal sleep not only requires adequate sleep quantity, but also includes characteristics such as sleep quality, timing, architecture, consistency, and continuity (Chaput et al., 2017).

1.2.4 24-hour Movement Behaviours and Guidelines Concepts and Definitions

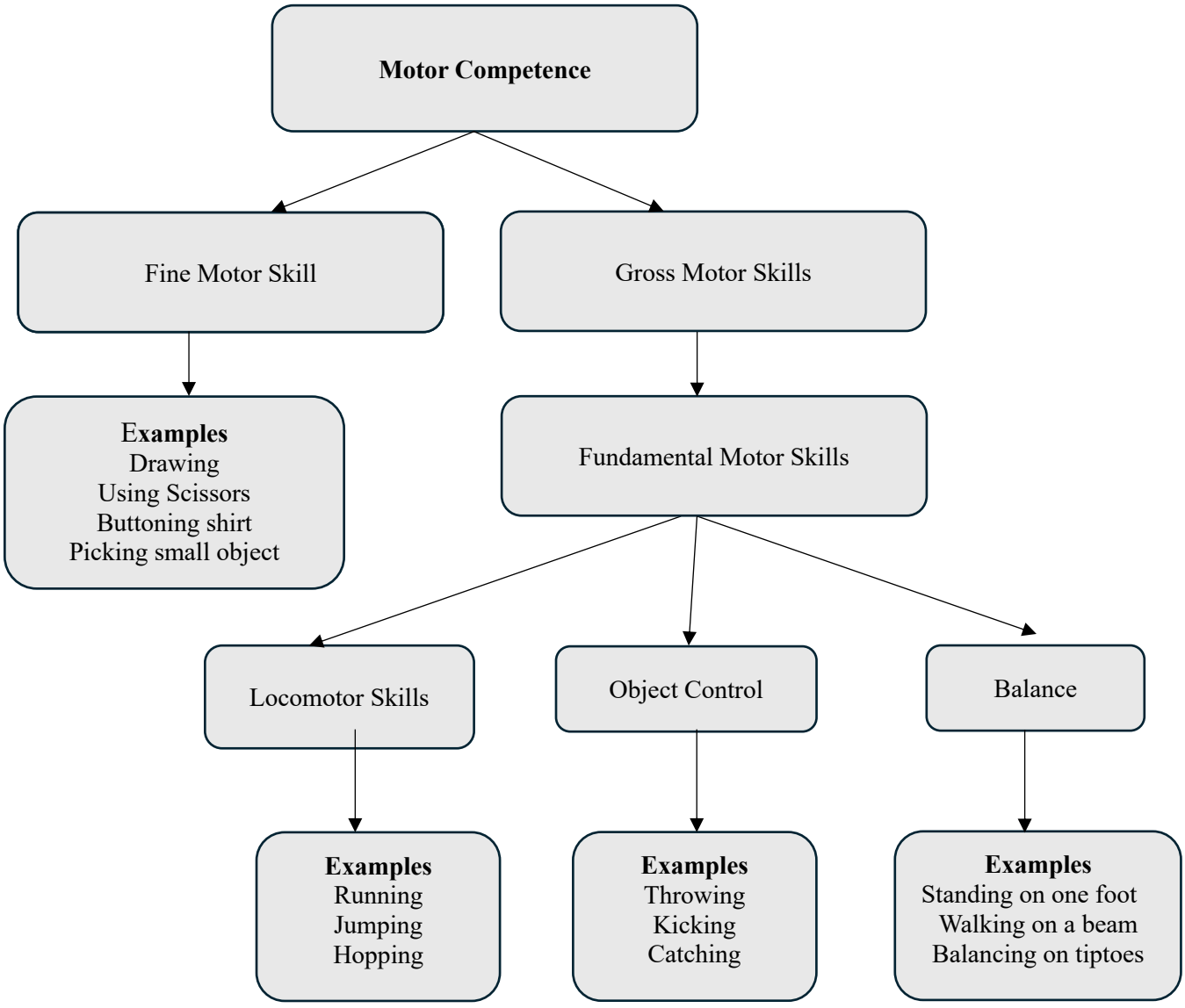
This term, as used in this thesis, refers to an umbrella concept encompassing the physical behaviours that occur along a movement-intensity continuum over 24 hours (Tremblay et al., 2016; Chaput et al., 2014). In this thesis, "24-hour movement behaviours" encompasses physical activity, sedentary behaviour, and sleep. The 24-hour movement guideline (may be used interchangeably with "24-hour movement recommendation" or the overall guideline for physical activity, sedentary behaviour and sleep in this thesis) refers to the World Health Organization's (2019) recommended amounts of physical activity, sedentary behaviour, and sleep within 24 hours for children aged 3-4 years, aimed at supporting their health and well-being.

1.2.5 Motor Competence Concepts and Definitions

Utesch and Bardid (2019) define motor competence as an individual's degree of proficient performance across a broad range of motor skills, as well as the underlying mechanisms, including the quality of movement, motor coordination, and motor control. "Motor competence" is one of the umbrella terms used in the literature to encompass multiple aspects of human movement skills (i.e., motor proficiency, motor performance, fundamental movement/motor skill, motor ability, and motor coordination) (Lopes et al., 2013; Robinson et al., 2015). The term "motor competence" as used in this thesis will therefore refer to an individual's ability to execute different motor actions, including coordination of both fine and gross motor skills, locomotor skills, object control skills and balance that are necessary to manage everyday life. In the context of this thesis, fine motor skills will refer to the use of small muscles for precise movements (e.g. writing or buttoning a shirt). In contrast, gross motor skills involve the use of

larger muscles for bigger actions (e.g. running or jumping). Locomotor skills enable the body to move from one place to another, including walking, hopping, and skipping. Object control skills involve handling and controlling objects using the hands or feet, such as throwing, catching, or kicking a ball. Lastly, balance refers to the ability to maintain stability and control of the body, whether standing still (static) or moving (dynamic). Subcategories and examples of motor competence are summarised in Fig. 1 below.

Fig. 1 Subcategories and Examples of Motor Competence



1.3 Background to the Thesis

1.3.1 The 24-hour Movement Behaviour Concept as it Applies to the Early Years

The early years (under 5 years of age) are a crucial part of children's development, during which rapid physical and cognitive development occurs (Janz et al., 2005). Physical activity, sedentary behaviour and sleep -referred to as movement behaviours because they fall on a movement/non-movement continuum based on intensity -have received increased attention due to their important role in healthy development and the health benefits for children in the early years (Tremblay et al., 2016; 2017). Since the whole day is made of 24 hours and time is finite, the effect of time use in one behaviour is dependent on the time it displaces from another behaviour, and a change to one movement behaviour would necessitate compensation from another movement behaviour. Since the movement behaviour continuum progresses from low- to high-intensity movement, a novel insight suggests that all three movement behaviours should be targeted to support children's optimal health (Kuzik et al., 2017; Chaput et al., 2014).

In the past, the health benefits of these movement behaviours were considered in isolation, with those of physical activity, particularly moderate-to-vigorous physical activity (MVPA), dominating discussions (Chastin et al., 2015). However, with these three behaviours co-dependent across the whole day (24-hour period), valuable information that can inform efforts to optimise the health of the paediatric population may be missed when considered individually (Carson et al., 2016). The consideration of the movement behaviours builds upon the traditionally strong emphasis on the health benefits of MVPA in children. While MVPA is undoubtedly an important movement behaviour, it only accounts for a small portion of the day (i.e., 24-hour period), whereas light-intensity physical activity, sedentary behaviour, and sleep make up most of the 24 hours (Carson et al., 2017). In recent years, there has been a paradigm shift, with studies showing that specific combinations of movement behaviours (i.e., high physical activity, low sedentary behaviour, and sufficient sleep) are associated with desirable health indicators such as motor development for the early years (Kuzik et al., 2017; Carson et al., 2016; Saunders et al., 2016).

1.3.2 Physical Activity and Health

Physical activity, as defined earlier, can be measured objectively (e.g., with accelerometers and pedometers) and subjectively (e.g., through diaries, self-report, or proxy report). In children under 5 years, most of their physical activities are unstructured and happen in different forms of play, including playing with blocks, messy play, jumping, walking, dancing, swimming, playing hide and seek, riding a bike, climbing or scooting as opposed to more structured activities like organised sports (Lee et al, 2020). A key interventional approach in curbing some public health issues of concern, such as obesity or cardiometabolic health in children, is increasing total physical activity energy expenditure (Belanger et al., 2022).

A systematic review by Carson et al. (2017) that examined the relationship between physical activity and health indicators in the early years (0-4) reported that higher durations and intensities of physical activity were positively associated with motor development, psychosocial health, cardiorespiratory fitness, and bone and cardiometabolic health. Another systematic review by Veldman et al. (2021) found moderate evidence for a positive association between physical activity and motor and cognitive development in children aged 3-5 years. Other systematic reviews have also consistently shown that physical activity in early childhood is linked to cognitive development, social-emotional development and motor competence in 0-6-year-olds (Laurent et al., 2021; Cj et al., 2021; Kuzik et al., 2017). Some studies have also indicated that children who engage in more active play are less likely to become overweight (Carson et al., 2016; Vaisto et al., 2014). Although these studies present evidence that physical activity in early years may be beneficial to their health and development, the type and amount (dose-response relationship) of physical activity needed in this age group for healthy growth and development remains unclear and may require further investigation. For instance, a systematic review by Laurent et al. (2021) on early childhood physical activity and cognitive or school-readiness outcomes concluded that despite a surge in research, results are heterogeneous and overall evidence quality remains low due to methodological variation. Hence, more rigorous, objective, and long-term research may be needed to determine optimal ‘doses’ of physical activity for different age groups within the early years.

1.3.3 Sedentary Behaviour and Health

Sedentary behaviour, as defined earlier, includes watching television, playing computer and video games, sitting time, stroller time, and screen time activities such as time spent on mobile phones and tablets. Although sedentary behaviour can be objectively measured with accelerometers and inclinometers, screen time, a component of sedentary behaviour, cannot be objectively measured and is assessed subjectively via self- or proxy-reports.

High levels of sedentary behaviours are increasingly prevalent and associated with poor health outcomes in children (Chaput et al., 2013; Santos et al., 2021). Extended periods of inactivity, particularly those involving screen time, have been shown to negatively impact physical, cognitive, and social development. A systematic review by Poitras et al. (2017) that examined the relation between sedentary behaviours and health indicators in the early years (0-4 years) showed favourable associations between interactive non screen-based activities (like reading/storytelling) and cognitive development; while screen-based and seated/supine sedentary behaviour were likely to have unfavourable or null associations with adiposity and motor development (Poitras et al., 2017).

Studies have shown that increased sedentary time and prolonged sedentary bouts have been associated with adverse health outcomes in children aged 0-5 years, including poor motor development, sleep disruption, and delayed cognitive and language development (Cliff et al., 2017; Chaput et al., 2017; Madigan et al., 2019). Prolonged sitting can hinder motor skill development, as physical activity is essential for refining coordination and building strength in early childhood (Caredot et al., 2018). Research indicates that children with sedentary habits exhibit weaker motor competence than their more active counterparts, as active play is crucial for honing coordination and strength during early childhood (Webster et al., 2019).

Screen time has become pervasive in modern society. Because of its role as a key contributor to sedentary behaviour, it is frequently highlighted as a specific sedentary exposure of interest in research studies (LeBlanc et al., 2017). While technology, such as smartphones, tablets, and television, can offer educational benefits when used appropriately, excessive screen time in early years has been linked to a variety of adverse effects. Several studies have reported the harmful effects of excessive screen time use on children's health and development (Aguilar et al., 2015; Beyens et al., 2018; Bhatt et al., 2019),

including short and unconsolidated sleep (Brockman et al., 2016; Cheung et al., 2017), poor motor skills (Felix et al., 2020) and visual problems (Huang et al., 2020; Yang et al., 2020). A longitudinal cohort study by Madigan et al. (2019) that explored the association between screen time and children's performance on a developmental screening test in children aged 2-5 years reported that excessive screen time can hinder children's optimal development (Madigan et al., 2019). In addition, a study by Carson et al. (2019) found that screen time during early childhood was associated with diminished social skills, such as understanding others' feelings and joining others in play.

In a systematic review by Li et al. (2020) exploring the relationship between screen time and health indicators in infants, toddlers, and preschoolers, the meta-analysis provided substantial evidence that excessive screen time was associated with overweight/obesity and shorter sleep duration among preschoolers. This systematic review, which included 80 studies (209,286 participants under age 7) from 23 countries, also reported that excessive screen time was associated with various health indicators in physical, behavioural, and psychosocial aspects in preschoolers (Li et al., 2020). With increasing studies reporting negative associations between children's screen time and health outcomes, it is important that researchers further explore the underlying factors contributing to this increased screen time.

Although many pieces of evidence point to negative associations between screen time and health, some researchers have argued that these findings are largely correlational and do not firmly support specific duration-based guidelines (Ashton & Beattie, 2019; Royal College of Paediatrics and Child Health, 2019). Instead, these researchers stress the importance of context and content of screen time and emphasise that addictive and passive patterns of screen time may be more harmful than the total time spent on the device. Future research may consider not just 'how much' children use screens, but also the purpose and conditions under which they use them.

In the context of movement behaviour frameworks, screen time and sedentary behaviour may be associated with both direct and indirect adverse health outcomes. Direct harms may include the increased risk of obesity, potentially due to exposures like unhealthy food advertising. Indirect harms of sedentary behaviour can occur through the displacement of physical activity and sleep. Screen time in early childhood is largely mediated by parental and caregiver decisions regarding access to digital

devices and media content (Radesky et al., 2020; LeBourgeois et al., 2017). While screens have become a common feature of modern family environments, their widespread availability means that they are frequently used as a convenient and accessible form of entertainment or distraction for young children. Parents may also use screen-based activities as practical tools to manage competing demands such as work responsibilities, household tasks, or caregiving for multiple children (Radesky et al., 2020; LeBourgeois et al., 2017). As a result, screen time can become a prominent part of daily routines in early childhood. However, when screen time displaces other movement behaviours such as physical activity, sleep, or interactive play, it may reduce opportunities for experiences that support healthy development (Chaput et al., 2017). This shift is particularly important in the context of the 24-hour movement behaviour framework, which emphasises the balance between physical activity, sedentary behaviour, and sleep. Excessive screen time has therefore been identified as a potential barrier to meeting recommended movement behaviour guidelines, particularly where prolonged sedentary screen activities replace time that could otherwise be spent in active play or adequate sleep.

1.3.4 Sleep and Health

The term sleep can be defined as a naturally recurring state of the body and mind characterised by altered consciousness, relatively inhibited sensory activity, inhibition of nearly all voluntary muscles, and reduced interactions with the surroundings (Gruber et al., 2014). As noted above, optimal sleep is essential for normal growth and development, emotional health, and immune function in children (Chaput et al., 2017). Sleep in the early years is important for healthy cognitive, psychosocial, and physical health (Liu et al., 2024; Hale et al., 2018). The term ‘healthy sleep’ can be defined by adequate duration, appropriate timing, good quality, and the absence of sleep disturbances or disorders (Gruber et al., 2020). Studies have shown that sleep duration decreases significantly from early childhood to adolescence, with sleep timing shifting predominantly to nighttime. (LeBourgeois et al., 2017). According to research, the relationship between sleep duration and health outcomes follows a U-shaped pattern, in which both insufficient and excessive sleep can negatively affect health (Chaput et al., 2017).

The benefits of sleep extend far beyond simply feeling rested; they influence a child's physical health, mental development, and emotional well-being, and are vital at every stage of development, from infancy through to adolescence.

Adequate sleep during the early years plays a critical role in children's overall health and development (Janssen et al., 2020). A systematic review by Chaput et al. (2017) provided evidence that longer sleep duration in children 0-4 years has favourable associations with adiposity, emotional regulation, growth, screen time, and risks/injuries (Chaput et al., 2017). Another systematic review by Reynaud et al. (2018) that explored sleep and its relation to cognition and behaviour in preschool-aged children found that greater sleep quantity or quality was linked to better behavioural and cognitive outcomes in preschool-aged children (Reynaud et al., 2018). Although this evidence highlights the importance of adequate sleep during the early years and its health benefits, additional research may be needed to better understand the relationships between various sleep characteristics and health outcomes during this period. Evidence discussed above is summarised in Table 1.

Table 1. Movement Behaviours and Health

Citation	Country	Study design/Type of evidence	Sample size & number of studies	Age	Exposure measures	Outcome measure	Direction of association
1.Poitras, et al. (2017).	Included studies from USA, Belgium, Australia, Canada, Germany and the Netherlands	Systematic review; synthesised evidence from studies published up to 2015	Included 96 (from 73 unique samples) studies with a total participant of 195,430	0-4 years	Sedentary behaviour (e.g., TV viewing, video gaming, iPad/tablet/touchscreen, smart phone, reading, puzzles, bouts, breaks, sedentary time, and screen time) measured via objective (accelerometery) and subjective (proxy-report)	Adiposity, motor development, psychosocial health, and cognitive development	Predominantly null associations between total sedentary time and adiposity and motor development; primarily unfavourable or null associations between screen time and adiposity, motor or cognitive development, and psychosocial health; Associations between time spent seated (e.g., in car seats or strollers) or in the supine position, and indicators of adiposity and motor development, were primarily unfavourable or null.
2.Kuzik et al., 2017.	Canada, Greece, USA, Scotland, Sweden	Systematic review; included studies published up to 2015.	7,436 (7353 unique participants) from 10 included studies	1-5 years (Mean age 3.29–4.97)	A combination of movement behaviours	adiposity, motor development, fitness, growth	Ideal combinations (low sedentary behaviour and high physical activity) were generally associated with improved motor development and fitness. Associations between adiposity and growth were inconsistent or nonsignificant.

3.Janssen et al. (2020).	USA, Korea, Germany, Japan, China, Australia, the Czech Republic, Spain, the UK, France, Canada, the Netherlands, New Zealand, Thailand, and Taiwan	Systematic review; included studies between 2010-2019	Included 31 studies with 60,445 total participants	0-4 years (preschoolers 3-4 years)	Physical activity and total sedentary behaviour via accelerometer; screen time via parent report	Sleep outcomes via parent report or accelerometer	Results indicate that excessive screen time is associated with poorer sleep outcomes in preschoolers.
4.LeBlanc et al. (2012).	USA, Canada, India, Thailand, Japan, Australia, New Zealand and the UK	Systematic review; Included studies published up to 2011.	Approximately 22,417 participants	0-5 years (preschoolers 3.1-4.9 years)	sedentary behaviour	Adiposity, Psychosocial health, Cognitive development, motor skill development, bone and skeletal health, and cardiometabolic health	TV viewing was negatively associated (unfavourable) with adiposity, psychosocial health, and cognitive development; dose–response evidence noted
5.Reynaud et al. (2018).	North American children (nine in the USA, six in Canada), Australia (four), Europe (five in total, one in each of the following: Switzerland, Italy, the Netherlands, Germany, and Finland), and Japan (two).	Systematic review; included studies published up to 2017	26 articles including 37,935 participants	24 to 72 months old.	Sleep duration	Cognitive and behavioural	Studies with the largest sample sizes found that a greater quantity or quality of sleep was associated with better behavioural and cognitive outcomes.

1.3.5 Integrated Movement Behaviours and Health in Early Years

Integrated movement behaviours refer to a holistic approach to physical activity, sleep, and sedentary behaviours that collectively contribute to a child's overall health and well-being. Over the past years, several studies have identified health benefits of these movement behaviours in isolation, with the focus mainly on MVPA and light physical activity (LPA). However, a paradigm shift in research has identified that physical activity cannot be viewed in isolation from other movement behaviours (sedentary behaviours and sleep) (Tremblay et al., 2017; Okely et al., 2018). Ignoring the other components of the movement continuum (i.e., sleep, sedentary behaviour, LPA), which make up approximately 95% of the day, and focusing only on the benefits of MVPA, which accounts for about 5% of the day, limits the optimisation of health benefits associated with movement behaviours. Besides the optimal balance of these behaviours being important for health, these movement behaviours also interact with each other.

Recent research has therefore shifted from examining the effects of individual behaviours- physical activity, sleep, or screen time- in isolation to a more holistic view that emphasises the balance of all three behaviours within 24 hours (Chaput et al., 2016). This integrated approach highlights how time spent in one activity inevitably affects the others (Farooq et al., 2018; Tanaka et al., 2014; Janssen et al., 2016). For example, regular physical activity can improve sleep quality, while good quality sleep can promote more physical activity (Dewald-Kaufmann et al., 2014). In contrast, excessive screen time can reduce both sleep quality and opportunities for light physical activity, particularly when screens are used at night (Hale et al., 2018; Janssen et al., 2020; Lan et al., 2020; Pearson et al., 2014). Reducing sedentary behaviour, especially screen time, can free up time for more active behaviours, creating a positive cycle that supports overall health (Tremblay et al., 2011). Some studies have suggested that the health benefits of MVPA can also be lost if children have inadequate sleep habits or engage in excessive screen time (Chong et al., 2021; Korcz et al., 2023; Sheldrick et al., 2018). Inadequate sleep can also reduce physical activity in some children due to fatigue and is associated with increased screen time, especially during late-night hours (Chaput et al., 2016). Excessive screen time may also reduce children's engagement in physical activity (Pederson et al., 2022). All three movement behaviours have

also been shown to interact with food intake, with excessive screen time and insufficient sleep increasing food intake, which can lead to unhealthy weight gain (Chaput, 2014; Thivel et al., 2013). Research that has included an integrated approach has shown that the composition and combinations of the three movement behaviours within 24 hours may have important health implications for children (Carson et al., 2016; Saunders et al., 2017).

By integrating the three movement behaviours, children may experience improved physical health, better cognitive function, emotional well-being, stronger immune systems, and better sleep, as research on behaviour change suggests that a comprehensive, holistic approach that includes all movement behaviours has a greater impact on health indicators (Pacheco et al., 2025; Silva et al., 2025; Prochaska, 2008). These interconnected factors support healthy development and create a foundation for a lifetime of healthy habits. This implies that examining the health implications of a single movement behaviour in isolation, as has been done previously, may miss key information that could inform efforts to optimise the health of the paediatric population (Carson et al., 2016).

1.4 Guideline Development: from Physical Activity to 24-hour Movement Guidelines

In the past, physical activity guidelines included some national recommendations on total physical activity for early years. For instance, in 2011, the UK published its first guidelines on physical activity for the early years (birth to school entry). This 2011 "Start Active, Stay Active" guidance was based mainly on expert opinion rather than evidence-based and was also limited to only a single quantitative recommendation that 3-4-year-olds should spend a minimum of 180 minutes in physical activity every day. In 2012, Canada also developed its first Canadian Physical Activity Guidelines for the Early Years (aged 0–4 years), and pre-schoolers (3-4 years) were recommended to accumulate at least 180 min of physical activity at any intensity spread throughout the day, including a variety of activities in different environments, activities that develop movement skills, with progression toward at least 60 min of energetic play by 5 years of age (Tremblay et al., 2012).

Considering the importance of an optimal time allocation during the whole day for overall health in early years, Canada introduced the 24-Hour Movement Guidelines for preschoolers (aged 3-4 years) in

2017, which was later adopted by Australia, South Africa, New Zealand, and the Asia-Pacific region (Tremblay et al., 2017; Loo et al., 2022). These guidelines state that preschoolers should accumulate at least 180 min of physical activity (of which, at least 60 min should be moderate-to-vigorous physical activity), ≤1 h/day of recreational screen time and not be restrained for more than 1 hour at a time, and 10–13 hours of sleep (Tremblay et al., 2017). Based on available and evidence-based research (Tremblay et al., 2017; Kuzik et al., 2017; Okeley et al., 2018), the WHO also published international guidelines on physical activities, sedentary behaviours and sleep for children under 5 years of age with recommendations on the amount of time that young children under 5 years should spend on each movement behaviour in 24 hours (WHO, 2019).

1.4.1 The 24-hour Movement Guidelines

In 2010, the WHO initially released global recommendations on physical activity for health, primarily to prevent non-communicable diseases through population-level physical activity, with the primary target audience being national policymakers (WHO, 2010). However, the recommendations addressed three age groups, which are individuals between 5-17 years old, 18–64 years old and those above 65 years and did not include children in the early years. In 2016, the WHO formed a Commission on Ending Childhood Obesity (WHO ECHO), anchored in the developmental origins of health and disease hypothesis, and published its first implementation report in 2017. The WHO ECHO reports emphasised the important roles of physical activity, sedentary behaviour, and sleep in the early years in the risk of obesity. Coupled with growing evidence of the importance of movement behaviours in the early years and the release of the integrated Canadian 24-hour movement behaviour guidelines in 2016, the WHO is set to produce guidance on time spent in these behaviours to prevent and treat obesity in young children and to improve other aspects of health and development. The WHO released guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age in 2019 (WHO, 2018), which did not only cover the previously underserved early years age group (0-4 years), but it also extended the guidance to include all three movement behaviours along the movement continuum (Tremblay et al., 2017).

The recommendation for 24-hour physical activity, sedentary behaviour and sleep for children under 5 years of age, also referred to as the 24-hour movement guidelines, is for all healthy children under the age of 5, irrespective of their gender, cultural background or socio-economic status of families, to support their healthy development (WHO, 2019). The recommendations for under 5s are subdivided into three population groups- infants (less than 1 year), children between 1 and 2 years old and children between 3 and 4 years old and are summarised in Table 2 below. The objective of the 24-hour movement behaviour guidelines for children under 5 is to promote active living from a very young age, encouraging habits that support optimal physical, cognitive, and social development. For children between 3 to 4 years old, it is recommended at least 180 minutes of physical activity (of which 60 minutes should be moderate to vigorous intensity), not to be restrained for more than 1 hour at a time, no more than 1 hour screen time per day, and at least 10 to 13 hours of good quality sleep in a day (WHO, 2019)

Although some of the studies cited throughout this thesis, particularly those by Chaput et al. (2016), Carson et al. (2016), and Tremblay et al. (2017) published between 2016 and 2017, may appear dated in relation to more recent literature, these papers constitute foundational and policy-informing evidence in the field of movement behaviours in early childhood. Evidence from these studies were instrumental in establishing the integrated 24-hour movement behaviour paradigm. These studies also directly underpinned the development of the Canadian 24-Hour Movement Guidelines for the Early Years and subsequently informed the WHO Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children Under 5 Years (2019). Given that the systematic review within this thesis was conducted in 2021, these publications represented the important and widely cited evidence at the time and remain key references underpinning current international movement behaviour recommendations.

Table 2. WHO Physical Activity, Sedentary Behaviour and Sleep Guidelines for Children under 5 years

Age	Physical Activity	Sedentary Behaviour	Good Quality Sleep
Less than 1 year	At least 30 minutes	0 minutes	14-17 hours (0-3 months); 12-16 hours (4-11 months)
1–2-year-olds	At least 180 minutes	0 minutes (age 1); 60 minutes (age 2)	11-14 hours
3–4-year-olds	At least 180 minutes (of which 60 should be moderate to vigorous)	Not more than 60 minutes a day on screen time; Not restrained for more than an hour at a time	10-13 hours

1.4.2 Prevalence of Meeting the 24-Hour Movement Guidelines

Since the release of the guidelines, several systematic reviews have examined levels of adherence to the 24-hour movement guidelines. Despite the well-established benefits of these guidelines, adherence to the overall movement guidelines remains low (between 3% and 14%) among children 0-5 years across different parts of the world, as reported by some systematic reviews (Chong et al., 2024; Feng et al., 2021; Tapia-Serrano et al., 2022) and individual studies (Okely et al., 2021; Kracht et al., 2020; McArthur et al., 2022; Chiaki et al., 2020; Hinkley et al., 2020). For instance, the recent systematic review by Chong et al. (2024), which pooled analysis on three movement behaviours (physical activity, screen time and sleep) in children 3-4 years from 33 countries reported that about 14% of participants met the overall guidelines for physical activity, screen time and sleep in under 5s (Chong et al., 2024). According to the review by Chong et al. (2024), which involved a total of 7,017 participants, about 49% met the physical activity guideline, 42% met the sedentary behaviour guideline, and 81% met the sleep guideline (Chong et al., 2024). Again, low adherence to the sedentary behaviour guideline was reported in the studies mentioned above, with about 15%-42% of children meeting it.

Although the early years guideline recommends the amount of time children should spend on screen time, children are typically experiencing much higher levels of screen time, exceeding the guideline (Ofcom, 2015, 2016; Okely et al., 2021). For example, a systematic review by Feng et al. (2021) exploring the association between meeting 24-hour movement guidelines and health in the early years showed that 28% of the participants met the screen time guideline. This review included 18 studies with 8,943 aged 0 to 5 years (Feng et al., 2021). Another systematic review and meta-analysis by McArthur et al. (2022), which explored the global prevalence of meeting screen time guidelines among children 5 years and younger, and included 89,163 children, also reported that about 36% of children aged 2 to 5 years met the guideline of no more than 1 hour a day of screen time. The review by Chong et al. (2024) mentioned earlier reported that, in the WHO European region, 50% of children aged 3-4 years met the screen time guideline (Chong et al., 2024). Findings from these reviews highlight the need for additional public health initiatives to promote healthy device use.

Low adherence to the screen time guideline could be attributed to the increased popularity of mobile devices, such as tablets and smartphones, for both educational and entertainment purposes among the early years age group in recent years (Chaudron, 2015; Papadakis & Kalogiannakis, 2017). The COVID-19 pandemic, which began in early 2020, also dramatically altered the daily lives of children and parents/caregivers worldwide, including how they interacted with their environments (Trott et al., 2022). Among the most significant shifts was the increase in screen time, especially in early childhood. With schools and daycares closing, social distancing measures enforced, and parents working from home, children spent far more time in front of screens- whether for educational purposes, entertainment, or communication with family and friends (Trott et al., 2022; Burkart et al., 2022). This surge in screen time has had profound implications for children's development. Studies suggest that numerous sociodemographic, lifestyle, and environmental factors, as well as family characteristics, may be associated with low adherence to the screen time guideline (Rollo et al., 2020). Given that low screen time adherence affects overall 24-hour movement guideline adherence in early years, it is important for researchers to examine the factors contributing to this low adherence and the impact of excessive screen time on children's health.

Overall, the high prevalence of excessive screen time among children is a cause for concern, as it potentially puts a significant proportion of children at risk for various negative health impacts. However, a key limitation is the lack of research examining how adherence to screen time guidelines differs across demographic groups, including age, gender, ethnicity, and socioeconomic status (SES). Identifying these disparities may be crucial for developing targeted interventions that address the specific needs of the at-risk population. Prevalence of guideline adherence to the individual and the overall guidelines is summarised in Table 3.

Table 3. Prevalence of Meeting the Individual Guidelines and the Overall Guideline for Physical Activity, Screen Time and Sleep

Citation	Country	Study design	Sample size/ Included studies	Age	% of participants meeting the physical activity guideline	% of participants meeting the screen time guideline	% of participants meeting the sleep guideline	% of participants meeting a combination of guidelines
1.McArthur et al. (2022).	North America (47.6%), with fewer studies from Australia/New Zealand (20.6%), Europe (17.5%), Asia (11.1%), Africa (1.6%), and the Middle East (1.6%)	Systematic review; included studies published up to 2021.	Included a meta-analysis of 44 studies	0-5 years	Not reported	35.6% of children aged 2 to 5 years met the screen time guideline	Not reported	Not reported
2.Feng et al. (2021).	Included studies from eleven countries	Systematic review; Included studies published up to 2020.	Included 18 studies, including 8,943 participants	0-5 years	The mean percentage of participants meeting the physical activity guideline was 67.0%	The mean percentage of participants meeting the screen time guideline was 28.3%	The mean percentage of participants meeting the sleep guideline was 77.3%	The mean percentage of participants meeting the 24-hour movement guideline was 12.8%
3.Chong et al. (2024).	Thirty-three countries of varying income levels across six geographical regions (4.1% Africa, 21.2% North and South America, 3.1% Eastern Mediterranean, 31.8% Europe, 3.4% South-East Asia, and 36.4% Western Pacific)	Systematic review; pooled dataset includes data collected between 2018 and 2022.	Included 14 studies with 7,017 participants	3-4 years	The mean percentage of participants meeting the physical activity guideline was 49.2%	41.8% of participants met the sedentary (screen time) guideline	The mean percentage of participants meeting the sleep guideline was 81.0%	The mean percentage of participants meeting the 24-hour movement guideline was 14.3%

4.Tapia-Serrano et al. (2022).	23 countries	Systematic review; Included studies published up to 2021.	Sixty-three studies comprising 387,437 individuals (26 studies in pre-schoolers)	3-18 years (Preschool age group not defined in the study)	Not reported	Not reported	Not reported	The mean percentage of participants meeting the 24hr movement guideline was 11.3%

1.4.3 Association Between Guideline Adherence and Health

Since the release of the 24-hour movement guidelines for under-5s, several researchers have examined the importance of adherence to the guidelines concerning health indicators. For example, Carson et al. (2019) in a cross-sectional study to determine associations between meeting the Canadian 24-hour movement guidelines for the early years and behavioural and emotional problems among 3-year-olds, found that meeting more recommendations within the guidelines was associated with fewer behavioural and emotional problems at 3 years (Carson et al., 2019). In a recent longitudinal study by Taylor et al. (2021) that looked into adherence to the 24-hour movement guidelines and psychological functioning in children (age 1-3.5 years), meeting all three movement guidelines was associated with lower anxiety and depression scores than in children who did not meet all the guidelines (Taylor et al., 2021).

A systematic review by Feng et al. (2021) examining the association between meeting the 24-hour movement guidelines and health in children under 5 years confirmed a positive association between meeting more guidelines and better psychological health-behavioural/emotional problems, psychological difficulties, and social-cognitive development (Feng et al., 2021).

A cross sectional study by Kuzik et al. (2022) that sought to examine the relationships between meeting the Canadian 24-hour movement guidelines and physical, cognitive, social-emotional, and overall development in early childhood (0-4 years) suggested that the ideal combination of the movement guidelines (e.g., sufficient sleep, low sedentary behaviour, high physical activity) was important for optimal health in the early years. The study showed that meeting the screen time and physical activity guidelines was both favourably associated with motor development and fitness among children aged 0-4 years, and a combination of adequate sleep and less sedentary behaviour was favourably associated with adiposity among infants and toddlers (Kuzik et al., 2022). However, a key limitation highlighted in the review was the reliance on a relatively small number of high-quality studies. This suggests that further research is needed to fully understand the relationship between various combinations of movement behaviours and a wide range of health outcomes in early years. The relationship between meeting the guidelines and health is summarised in Table 4 below.

Table 4. Meeting the Movement Behaviour Guidelines and Health Outcomes

Citation	Country	Study design/Type of evidence	Sample size & number of studies	Age	Exposure measures	Outcome measure	Direction of association
1.Feng et al. (2021).	Included studies from eleven countries	Systematic review; included studies published up to 2020.	Included 18 studies, including 8,943 participants	0-5 years	Physical activity and sleep - objectively measured (using pedometers, accelerometers) or subjectively measured (using self-reported or proxy-reported questionnaire, interview, diary). Screen time - subjective measurement (e.g. self-reported or proxy-reported questionnaire, interviews, diary)	Psychosocial health, motor development, and cognitive development	Meeting the screen time guideline and the 24-hour movement guideline was associated with fewer behavioural and emotional problems; meeting the screen time guideline was positively associated with locomotion and ball skills in 3-year-olds; meeting the screen time guideline at baseline (3.2 years old) was positively associated with fundamental motor skills at one-year follow-up.
2.Kuzik et al. (2022).	Canada	Cross-sectional; Data collected between 2012-2016	95 participants	3-5 years	Physical activity and total sedentary behaviour via accelerometer; sleep time via parent report	Physical, cognitive, social-emotional, and overall development	Meeting sleep recommendations alone, as well as the combination of sleep and physical activity recommendations, were associated with better physical and overall development in this sample.

1.4.4 Correlates of Sedentary Behaviour

Factors predicting and correlating with screen time are variables that may impact the amount of screen exposure children experience. These factors are diverse and multifaceted, highlighting the intricate ways modern technology interacts with family relationships, parenting styles, and societal pressures. Certain predictors of screen time are modifiable, suggesting that adjusting these variables could reduce children's screen time. Correlates of screen time include demographic, sociocultural, environmental, and parental factors that affect both the duration of young children's screen time and its consequences.

A) ***Demographic Factors***- demographic factors such as age, gender, socioeconomic status (SES), and parents' educational levels can influence children aged 0-4 years' screen time (Paulus et al., 2024). Research indicates that children from lower-SES backgrounds often have higher screen time, as low-income families may rely more on screens for entertainment or to manage busy schedules (Radesky et al., 2014). A systematic review by Shalani et al. (2021) found that introducing screen time at a younger age influence later usage patterns, with earlier exposure associated with increased screen time as children grow older. Similarly, Pons et al. (2020) observed that children (aged 2-6 years) from households with parents who have higher educational attainment tend to have lower screen time, as such parents are more likely to be aware of the risks of excessive screen time, establish limits, and engage their children in alternative activities. (Pons et al., 2020).

B) ***Environmental Factors-*** The environment in which children grow up can influence screen time. A home environment that encourages physical activity (e.g., a backyard or playground) and limits screen time in favour of active play is associated with lower screen time in young children. For example, households with limited screen-based entertainment options or those that prioritise outdoor play may encourage children to spend more time engaging in physical activity rather than sedentary screen activities (Vanderloo et al., 2020; Katzmarzyk et al., 2019). Also, the presence of multiple screens in the home, such as smartphones, tablets, and computers, increases the likelihood that children will spend more time on screens (Muppalla et al., 2023;

Emond et al., 2020). Robinson et al. (2017) highlight that families with access to several screen devices may find it easier to let children engage with screens in various contexts, whether for educational purposes or entertainment (Robinson et al., 2017).

C) ***Parental Factors***- Some parenting practices, attitudes, behaviours and strategies can affect children's screen time use. For instance, a systematic review examining parental influences in children aged 6 years and below concluded that parental screen time was positively associated with young children's screen time (Xu et al., 2015). Parents who frequently use screens themselves are more likely to have children who engage in excessive screen time, reflecting shared family routines and norms (Muppalla et al., 2023). Again, different parenting styles influence how children's screen time is managed. More structured and responsive parenting approaches, such as setting consistent limits and encouraging alternative activities, are associated with lower screen time, whereas less restrictive approaches are linked to higher use (Radesky et al., 2020). Recent qualitative and mixed methods research further suggests that parents' decisions around screen time are often shaped by contextual factors such as time constraints, work demands, and the perceived educational value of digital media (Chong et al., 2023).

D) ***Sociocultural Factors-*** some cultural attitudes and societal norms may influence children's screen time use, as well as shaping how parents perceive and manage screen time for their children. Some cultures view screen time as a positive educational tool, while others emphasise non-digital forms of play and learning (Chong et al., 2023). In countries with high access to digital technology, screen time is often integrated into early childhood education settings such as daycare centres and nurseries, whereas in other cultures, outdoor play and direct social interactions may be prioritised (Mallawaarachchi et al., 2024). Parents' beliefs about the benefits and harms of screen time play a significant role in how they manage screen time. Some parents may perceive screens as valuable for educational purposes, while others view excessive screen time as detrimental to children's development. Parents' attitudes toward screen time often align with their understanding of its effects on learning, social skills, and physical health (Radesky et al., 2014).

Most studies have focused on understanding the role that screen time correlates play in influencing children's screen time, as mentioned above. However, the reciprocal effects of screen time on these correlates (e.g., family dynamics and child behaviour), which may be crucial for understanding bidirectional relationships and for developing effective interventions, have been less explored. Further research is needed to explore the causal and reciprocal relationships between screen time and its correlates. Again, while parental influence is recognised as a significant factor in determining children's screen time, there is a lack of research exploring the precise parental practices and beliefs that either support or hinder adherence to screen time guideline. This is a critical area for further investigation, especially considering the crucial role parents play in shaping children's screen habits in the early years (Niiranen et al., 2024).

1.4.5 An Ecological Framework to Explore the Influences of Children's Screen Time

Urie Bronfenbrenner's bio-ecological model of human development, rooted in his ecological systems theory (1979), views human growth as occurring within and shaped by a complex web of interconnected relationships. This model highlights the dynamic interactions between individuals and their various environments, showing how personal, social, and cultural contexts influence development throughout life. These relationships are shaped by multiple levels or systems in the surrounding environment, from immediate settings such as family, home, or school to the larger societal and cultural context in which a child is raised (Bronfenbrenner, 1979). This implies that children's movement behaviours, including screen time, are not just influenced by their immediate environment but also by the various aspects and reciprocal interactions within it and in the larger environment.

Bronfenbrenner conceptualised human development as occurring within a series of nested systems- microsystem, mesosystem, exosystem, and macrosystem- each interacting with and influencing the others. This ecological model provides a valuable framework for understanding and analysing the factors that shape screen time behaviour in 3-4-year-old children. According to Bronfenbrenner (1979), early childhood is a crucial phase of development, during which environmental factors play a significant role in shaping developmental outcomes.

Bronfenbrenner's ecological systems theory has undergone numerous adaptations and revisions over the years, reflecting a deeper understanding of human development and the influence of various environmental contexts. Although the foundational principles of the model remain intact, Bronfenbrenner's original framework has evolved into variations that offer a more detailed perspective on how environmental systems affect development. One such adaptation, the socio-ecological model, refined by McLeroy et al. (1988) and used as a framework for health promotion programs, will be used to explore factors influencing screen time among 3- to 4-year-olds. The socio-ecological model identifies five levels- individual/intrapersonal, interpersonal/relationships, institutional/organisational, community, and public policy- summarised in Fig. 2 below.

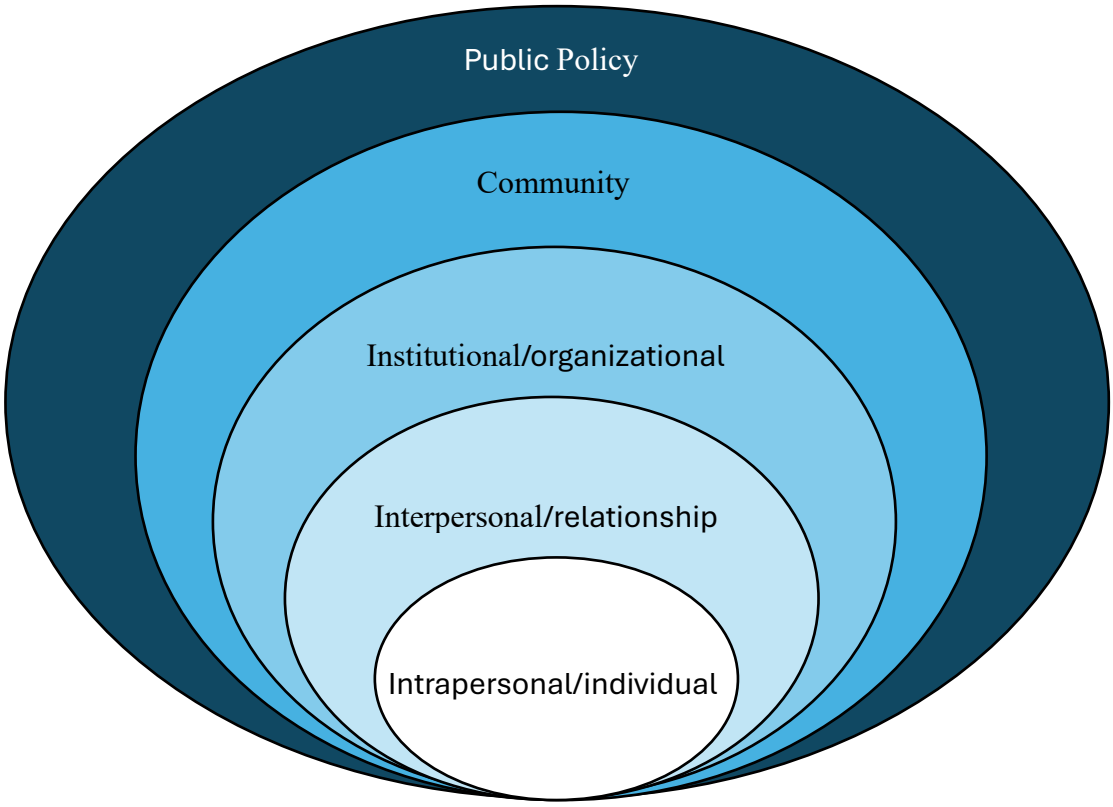


Fig 2. Socio-Ecological Model for Health Promotion, adapted and redrawn from McLeroy and colleagues (McLeroy et al., 1988)

The socio-ecological model offers a framework for understanding the various levels of influence that shape movement behaviours, including screen time during early childhood. It acknowledges that

children's screen time is affected not only by individual factors but also by a combination of interpersonal, organisational, community, and societal influences. As a result, effective interventions to reduce excessive screen time in children should address these multiple levels to maximise their impact.

1) ***Intrapersonal/Individual***- This focuses on the characteristics of the individual, such as age, sex, ethnicity, developmental stage, cognitive abilities, self-efficacy, personality traits or temperament that may influence their screen time use. These characteristics shape how children engage with screen time. Some studies report that screen time increases with age (Anderson & Pempek, 2005), while others show that some children may be more susceptible to excessive screen time due to characteristics such as impulsivity, attention-seeking behaviour, or social isolation (McArthur et al., 2022).
2) ***Interpersonal Level-*** This level explores the social connections that influence children's screen time. Family dynamics and parental practices play a crucial role. For instance, parents who set clear rules around screen time may have children with less screen time. (Vandewater et al., 2007). Additionally, when parents actively participate in screen-based activities with their children, it may help moderate their screen time. Peer influences also shape children's screen time, especially as they get older, as they may be influenced by the screen time behaviours of their friends or classmates, increasing their likelihood of adopting similar habits (LeBlanc et al., 2012).
3) ***Institutional/Organisational Level-*** At the institutional or organisational level, this model explores the influence of schools, daycare centres, and other establishments on how children interact with screens. These institutions shape an environment that can either encourage or restrict children's screen time. For instance, although many daycare, nursery, and school settings may utilise educational technologies such as tablets and computers, poor management of these tools can lead to an overall increase in children's screen time.
4) ***Community Level-*** This level examines the broader connections within community settings, including the accessibility of recreational facilities, the overall built environment, and the community and societal norms that might affect children's screen time. For instance,

communities that offer outdoor play areas, indoor recreational facilities, and organised physical activities, such as parks and sports leagues, are likely to encourage children to engage in more physical activities, which can help decrease their screen time. Additionally, the prevailing norms and values in a community can influence what is deemed an acceptable amount of screen time for children. In communities that do not emphasise physical activity or where prolonged screen time is considered typical for children, children's screen time will likely be higher.

5) ***Public Policy-*** This section of the model looks at national laws and policies that may impact children's screen time. These factors encompass media advertising, regulations, and the broader digital landscape, such as social media platforms. Government rules and policies regarding screen time can help establish standards for what constitutes appropriate use by children. In today's digital world, numerous media companies actively promote screen-based products to children, including video games and social media applications, thereby heightening their interest in these devices and encouraging overuse (Zimmerman & Christakis, 2005). Without adequate regulation, the prevalence of ads targeting children can lead to increased screen time both in homes and public areas.

This thesis utilises key aspects of Bronfenbrenner's socio-ecological model for health promotion as a theoretical framework to examine the impact of screen time on 3-4-year-olds and to explore parents' perspectives on the factors influencing screen time in this age group**.** The socio-ecological model (SEM) was chosen as the conceptual foundation for this study because it offers a holistic framework for understanding health behaviours as the outcome of interactions across multiple levels of influence, namely individual, interpersonal, organisational, community, and policy factors (McLeroy et al., 1988). Unlike behaviour models that focus predominantly on individual-level determinants, such as the COM-B model (Capability, Opportunity, Motivation–Behaviour) (Michie et al., 2011), the SEM recognises that behaviours, including children's screen time and sedentary behaviour, are shaped by broader social, structural, and environmental contexts. This framework has also become widely adopted in public health research precisely because it situates behaviour within these interconnected systems, allowing researchers to consider how personal choices are influenced by social relationships, environmental

opportunities, and policy conditions (McLeroy et al., 1988). Such a multi-layered perspective is especially relevant in early childhood, where routines and behaviours are shaped collectively by parents, caregivers, childcare settings, and the wider societal environment.

Alternative theoretical approaches, such as Bandura's Social Cognitive Theory (SCT), highlight the dynamic interplay between personal factors, behaviour, and the environment (Bandura, 1986). However, like the COM-B model, SCT primarily concentrates on individual behavioural mechanisms and may not fully reflect broader structural influences, such as community resources or policy frameworks, that shape families' daily routines and children's opportunities for active play and movement. The SEM, by contrast, explicitly incorporates these broader contextual dimensions, making it especially well-suited for investigating behaviours situated within family and societal systems.

Parental decision-making plays a central role in shaping young children's exposure to screen time. During the early years, children have limited autonomy over their daily routines, meaning that parents and caregivers largely determine when and how screens are used. A synthesis of qualitative studies highlights that parents often balance perceived educational benefits of digital media with concerns about excessive use, frequently relying on screens as practical tools to occupy children while managing competing demands such as work or household responsibilities (Chong et al., 2023). Parents also sometimes use strategies such as setting time limits, selecting age-appropriate content, or engaging in co-viewing to guide children's media experiences. Recent evidence from a systematic review by Mallawaarachchi et al. (2024) suggests that the context of screen time, including the type of content, purpose of use, and whether screens are used jointly with caregivers, may be as important as total screen time when considering developmental outcomes. This systematic review and meta-analysis found that program viewing (actively watching TV content) and background television exposure (TV being on in the environment while the child is not actively watching it) were associated with poorer cognitive outcomes, while caregiver co-use of media was associated with more positive cognitive outcomes in early childhood (Mallawaarachchi et al., 2024). Importantly, parental oversight and co-viewing are typically more prevalent during the early years compared with later childhood or adolescence, when

children gain greater independent access to digital media. Therefore, understanding how parents mediate and contextualise children's screen time is important for developing recommendations that are realistic.

Within the SEM framework, the qualitative component of this thesis (Study 3) examined parental influences on young children's screen time and sedentary behaviour. This was due to the key role parents play in children's daily routines, and the influence they have on their movement behaviours including screen time. While parental decision-making plays an important role in shaping children's screen use, it is also important to recognise that these behaviours occur within broader structural contexts, as described in the outer levels of the socioecological model. Several wider environmental and policy-related factors may indirectly influence how families manage children's screen time and sedentary behaviours. For example, parental work patterns and childcare availability, often shaped by national labour policies and childcare provision, can affect the amount of time parents have available for supervising or engaging children in alternative activities (Radesky et al., 2020; Hale et al., 2018). In many contexts, parents must balance employment demands with caregiving responsibilities, which may increase reliance on convenient strategies such as screen time to engage children and keep them occupied. Similarly, policies relating to early childhood education and childcare hours, affordability of childcare services, and access to community facilities can influence the structure of children's daily routines (WHO, 2019; UNICEF, 2020). At the community level, neighbourhood safety, access to parks and recreational spaces, and seasonal or climatic conditions may also shape opportunities for outdoor play and active engagement. These broader structural influences highlight that parents' management of children's screen time is not solely an individual or family-level issue but is embedded within wider social, environmental, and policy contexts that shape everyday family life. Consequently, the qualitative findings offer valuable insights into the interpersonal domain while underscoring the importance of broader contextual influences on parental decision-making.

1.5 Motor Competence in Early Childhood

One of the main pillars of adopting a physically active lifestyle is motor competence (Goodway & Gallahue, 2012). For example, successful participation in many structured and non-structured activities, games, and sports (such as hopscotch, cricket, four-square, tennis, basketball, and dance) demands a certain level of competence in many fundamental motor skills like running, catching, throwing, hopping, balance, and striking (Robinson et al., 2015).

Motor competence, as defined earlier (Utesch and Bardid (2019), is a crucial part of a young child's development and has been considered as a foundation for physical activity in young children during early and subsequent years as well as a key factor in predicting higher levels of children's health-related physical fitness, engagement in physical activities, and overall improved health outcomes. (Stodden et al., 2008; Gallahue et al., 2012; Barnett et al., 2016; Utesch, Bardid and Büsch, 2019). Motor competence involves the development of a child's musculoskeletal system and the acquisition of gross motor skills and fine motor skills. Fine motor skills include movements of the hands, wrists, fingers, feet, toes, lips, and tongue, whereas gross motor skills involve the development of muscles that enable babies to hold up their heads, sit, crawl, and eventually walk, run, jump, and skip. The development of motor competence in children is an expression of the integration of many physiological systems, including the musculoskeletal, cardiorespiratory, sensory, and neurological systems, and their ability to interact with the environment (Dwyer et al., 2009; Malina, 2014). Motor competence can also be seen in the ability to perform fundamental motor skills (FMS) proficiently during childhood (Utesch & Bardid, 2019). Fundamental movement skills are basic patterns of movement, such as running, jumping, and catching (Gallahue & Ozmun, 2006), and are generally classified into three constructs. These are locomotor skills (e.g., run, hop, jump, slide, gallop, and leap); object control/manipulative skills (e.g., strike, dribble, kick, throw, underarm roll, and catch) and stability/non-locomotor skills (e.g., balancing, body rolling, bending, and twisting) (Gallahue et al., 2012).

1.5.1 Correlates of Motor Competence

The development of motor competence during childhood is generally dependent upon and influenced by both biological (such as genetics, sex, and maturation) and environmental factors (such as gender roles, SES, stereotyping, experiences, opportunities to play, encouragement, demographics, and social factors) (Thomas et al., 2005; Barnett et al., 2016; Venetsanou & Kambas, 2010). Biological and environmental constraints (Gabbard, 2009) affect growth and motor competence, which can either positively or negatively influence physical activity participation. Research has shown a connection between environmental contexts (aspects of the home, school, culture, and psychological and social influences) and motor competence, which is supported by Bronfenbrenner's Ecological System (Bronfenbrenner, 1992). Understanding these correlates can help identify ways to support children's motor skill development. Some correlates of motor competence acquisition include:

1) ***Age-*** Age is a significant correlate of motor competence, as children's motor skills develop through stages. Motor competence is typically acquired in a predictable sequence, with children mastering gross motor skills (e.g., running, jumping) before fine motor skills (e.g., drawing, writing). Younger children, especially those under 3, may have less refined motor skills, while older children demonstrate more complex motor coordination (Bower et al., 2015). The maturation of the nervous system and the development of muscle strength over time allow for greater motor control and precision.
2) ***Genetic Factors***- Genetic predispositions play a fundamental role in the development of motor competence. Research suggests that children inherit traits related to physical abilities, such as balance, strength, and coordination, which can influence the development of motor skills (Zhou et al., 2018). While genetics sets a baseline for motor ability, environmental factors and opportunities for practice are critical for skill development
3) ***Socio-economic Factors***- Some studies have reported that children from higher socioeconomic backgrounds tend to have more access to resources that support motor development, such as extracurricular activities, sports clubs, or private lessons (O'Connor et al., 2015). A study by Niemistö et al. (2019) has shown that family factors, such as the educational level of parents, can also be associated with a child's perceived motor skill (PMS) (Niemistö et al., 2019).

Additionally, SES influences the quality of childcare and educational settings, which, in turn, can affect motor competence.

4) ***Environmental Factors***- According to the socioecological model, the environment plays an important role in the possibilities a child has to interact actively with the environment (Bronfenbrenner, 1979). Environmental factors, such as access to outdoor play areas, parks, and playgrounds, influence children's motor competence. Children who have more opportunities to engage in free play, especially in natural environments, are likely to develop better motor skills. The physical environment not only provides opportunities for active play but also promotes the development of specific skills, such as balance and coordination (Tremblay et al., 2010). Niemistö et al. (2019) also highlight that less access to electronic devices, which is an environmental factor, was associated with better perceived locomotor skills in five- to seven-year-olds (Niemistö et al., 2019).

Although individual, biological, and sociological factors influence the acquisition of motor competence, as mentioned above, little is known about how they interact to shape it. Further research may be required to understand the interactions among multiple factors and provide a comprehensive perspective on the drivers of motor competence during the early years.

Motor competence in early childhood is not shaped by individual factors alone, but also strongly influenced by environmental, organisational, and the policy factors that sit in the outer rings of the socio-ecological model. From an environmental and community perspective, access to safe play spaces such as parks, playgrounds, and open green areas provides children with frequent opportunities to practise fundamental movement skills, which supports the development of their motor competence. Again, features of the built environment, such as walkability, the availability of recreational facilities, and neighbourhood design, can facilitate or constrain active play (Pate et al., 2016). Weather and seasonal conditions (long periods of cold, rain, or darkness) may further restrict children’s outdoor play and thus indirectly limit opportunities to develop and refine their motor skills.

At the organisational level, early childhood education and care settings play a key role in shaping movement opportunities which in turn, improves motor competence. Provision of adequate and varied play equipment, such as outdoor play areas, climbing structures, and balls or other portable equipment, supports skill practice across different domains (locomotor, object control, and balance) (Taylor et al., 2024). Studies have shown that engaging in regular physical activity, particularly activities that challenge balance, coordination, and strength, has been positively associated with the development of fundamental movement skills, which form the basis for more complex movement patterns later in life (Barnett et al., 2016). Settings with limited space, few resources, or a strong academic focus at the expense of movement may inadvertently restrict children's opportunities to acquire and develop their motor skills (Taylor et al., 2024). At the policy level, movement behaviour guidelines and early childhood physical activity policies can shape environments that promote skill development. Together, these outer SEM influences affect the opportunities children have to engage in movement experiences that support motor competence development.

1.5.2 Motor Competence and Health

The acquisition of motor competence in the early years has been linked to improved health indicators, such as cardiorespiratory fitness and reduced adiposity (Stodden et al., 2008). Research has shown that children with better motor competence are more likely to be active and engage in high levels of physical activity, which is associated with improved cardiovascular, cognitive, and mental health (WHO, 2019; Carson et al., 2017). Children with low motor competence are more likely to be physically inactive from childhood through to adulthood and may prefer a less active lifestyle to avoid movement difficulties, which may increase the risk of obesity (Wrotniak et al., 2006). Again, some studies have found positive associations between motor competence in the early years and cognitive skills (Piek, Dawson, Smith, & Gasson, 2008) and that children who develop better motor skills in the early years may show higher executive functioning, which benefits their academic achievement (Schmidt et al., 2017).

Emerging research provides evidence that supports associations between motor competence and a range of health outcomes. For example, a systematic review by Cattuzzo et al. (2016), which explored the relationship between motor competence and health-related physical fitness (HRPF) in children and adolescents, established a positive association between motor competence and cardiorespiratory fitness (Cattuzzo et al., 2016). Another systematic review by Figueroa and Ann (2017) examining motor competence and physical activity in 3-5-year-olds also reported a significantly positive relationship between the two in 8 of the 11 included studies (Figueroa & Ann, 2017). In a more recent systematic review by Barnett et al. (2022), which provides insight into motor competence and health in children and adolescents (aged 2-18 years), there a was strong positive evidence for a pathway from motor competence to fitness and indeterminate evidence for the reverse, with strong evidence indicating that locomotor/coordination predicted muscular strength/endurance and some evidence for cardiovascular endurance as an outcome of motor competence (Barnett et al., 2022). Another recent systematic review by Liu et al. (2023) also looked at the correlation of FMS with health-related fitness elements in children and adolescents (aged 3-16 years) and reported that fundamental movement skills, object manipulation, locomotor and balance skills were all significantly and positively related with cardiopulmonary function and muscle strength and endurance (Liu et al., 2023). Table 5 summarises the relationship between motor competence and health.

MOTOR COMPETENCE AND HEALTH

CITATION	Country	Study design/Type of evidence	Sample size & number of studies	Age	Exposure measure	Outcome measure	Direction of association
Schmutz et al. (2020).	Switzerland	Longitudinal study: Data collected between 2014-2016	550 participants	2-6 years old	Motor competence-assessed with the Zurich Neuromotor Assessment.	Physical activity	Motor competence and physical activity developed independently of each other in early childhood. Although measures of quantity and intensity of physical activity were not related to motor development, specific movement experiences and practice—which are not reflected by the accelerometer—may be needed for skill development.
Barnett et al. (2022).	N/A	systematic review; Included studies up to 2020	43 articles included for extraction	2-18 years	Motor competence	PA, weight status, health-related fitness, perceived MC	1)Strong evidence in both directions for a negative association between MC and weight status. 2) Strong positive evidence for a pathway from MC to fitness and indeterminate evidence for the reverse. 3) Indeterminate evidence for a pathway from MC to PA and no evidence for the reverse pathway. 4) Insufficient evidence for the MC to perceive the MC pathway. 5) Strong positive evidence for the fitness-mediated MC/PA pathway in both directions. 6) Indeterminate evidence for the perceived MC-mediated pathway from PA to MC and no evidence for the reverse

1.5.3 Concerns Over Motor Competence in the Early Years

In recent years, reports of decreased motor competence among children in some countries have raised concerns (Vandorpe et al., 2011; Hardy et al., 2013; Tester et al., 2014). Research has revealed a global decline in motor competence among children (Hardy et al., 2013; Sgrò, Quinto et al., 2017; Sgrò, 2018; Sgrò, 2019). For example, according to Duncan et al. (2022), the motor competence of children and adolescents in the United Kingdom and Ireland is now concerningly low (Duncan et al., 2022). Some studies have also shown that only 50% of children demonstrate competency in a broad range of fine and gross motor skills (Bryant et al., 2013; Spessato et al., 2013). A systematic review by Rao et al. (2023) that used data from nationwide studies in China to assess early motor competence in 4-year-olds revealed a significant decline in children's motor competence from 2013 to 2017 (Rao et al., 2022). The review explained that the decrease in motor skills from 2013 to 2017 across different regions of China may be due to several environmental and stimulation-related factors, including increased screen time. This is not the first study to link increased screen time to a decline in motor competence in children. Increased children's screen time has been linked to reduced motor competence among Canadian children (Cardoret et al., 2018). It is therefore important to examine and monitor motor competence during early childhood to provide appropriate strategies to support children's motor development.

1.6 The Current Thesis- Rationale for Focusing on Sedentary Behaviour

Despite the growing emphasis on early childhood movement behaviours, current evidence indicates that 3-4-year-olds are not meeting screen time and sedentary behaviour guideline, as summarised in section 4.2 above. Excessive screen exposure and sedentary behaviour are increasingly prevalent among children as young as 3 to 4 years old, raising concerns about multiple aspects of health and development, including motor competence acquisition. In particular, it is not well understood whether these behaviours affect different domains of motor development, such as locomotor skills, object control or balance, in distinct ways. Again, the specific relationship between screen time/sedentary behaviour and motor competence remains unclear in 3-4-year-olds. Although early years are generally an important

window for children's development, the 3-4 year group is particularly significant due to the rapid growth across physical, cognitive, emotional, and social domains, which lays the foundation for future learning, behaviour, and health. Hence, the impact of sedentary behaviour on 3-4-year-olds' health outcomes, such as motor competence, may differ from its impact on babies and toddlers.

Sedentary behaviour is a key component of the integrated 24-hour movement framework, yet it remains less well understood than physical activity and sleep, particularly in young children. Within this domain, screen time represents a distinct and modifiable behaviour with increasing relevance in modern childhood. With a majority of studies reporting low adherence to the overall guideline for physical activity, screen time and sleep and the sedentary behaviour guideline (screen time guideline) as highlighted in this chapter, it is important for research to examine factors contributing to low adherence to these guidelines. It is often identified as a primary contributor to low adherence to movement guidelines and has the potential to displace developmentally beneficial activities, including physical play, social interaction, and sleep. However, much of the existing research has either focused on movement behaviours collectively or placed greater emphasis on physical activity, potentially underestimating the independent contribution of sedentary behaviour and screen time to health outcomes such as motor competence.

Furthermore, while some quantitative studies have begun to explore movement behaviours in young children, there is a lack of qualitative research that seeks to understand the underlying factors influencing screen time and sedentary behaviour in 3-4-year-olds. Parents' beliefs, home environments, and socio-cultural norms likely play a critical role, but these influences have not been sufficiently investigated. Few studies that have examined stakeholders' perceptions and views on the acceptance of the movement guidelines have focused on older children or the early years population as a group. For instance, some studies (Stanley et al., 2020; Riazi et al., 2017) that explored stakeholders' perceptions of the acceptability, usability, and dissemination of the 24-hour movement guidelines in Australia and Canada involved young children aged 0-5 years.

Taken together, these gaps highlight the need for a more focused and multi-dimensional investigation of sedentary behaviour and screen time in 3–4-year-olds. Such evidence is vital to inform more targeted and developmentally appropriate interventions and guidelines. By examining both the associations with motor competence and the underlying parental and contextual influences, this thesis aims to provide a more nuanced understanding of how these behaviours operate within the broader 24-hour movement framework, thereby contributing to a more comprehensive and developmentally sensitive evidence base.

1.6.1 Aims of the Current Thesis

1) Given the potential gaps in evidence regarding the relationship between sedentary behaviour and motor competence in 3- to 4-year-olds as highlighted in this introduction, the first study of this thesis examined the associations between both screen time and habitual sedentary behaviour, and their association with different components of motor competence (fundamental motor skills, fine and gross motor skills, locomotor skills, object control and balance) in 3- to 4-year-olds.
2) Based on the findings from the first study in this thesis, the second study aimed at examining the association between a) screen time (hours/day) and total daily accelerometery measured sedentary behaviour (hours/day) and gross and fine motor skills; b) meeting the sedentary behaviour guidelines (restraint and screen time guideline) and fine and gross motor skills using a representative data sample from the SUNRISE international study.
3) Finally, as this chapter has highlighted the detrimental effects of excessive screen time on children's health and development, there is a clear need for a deeper understanding of screen time in 3-4 year olds, to inform effective interventions. Hence, study 3 of this thesis explored parents' perceptions of barriers and facilitators to meeting the screen time guideline, as well as differences in perceptions between those who meet and those who do not meet the guideline.

1.6.2 Summary of Research Gaps and Aims

Despite growing concern about the potential negative impact of excessive screen time and sedentary behaviour on young children's development, there remains limited evidence on how these behaviours relate specifically to motor competence, particularly in 3- to 4-year-olds. Most existing research has focused on older children or has not adequately differentiated between types of sedentary behaviour (e.g., screen time vs. total sedentary time), nor thoroughly explored their associations with specific components of motor competence, such as fine, gross, locomotor, and object control skills and balance.

Additionally, there is a lack of international, representative data examining how adherence to sedentary behaviour guidelines (including screen time and restraint-based guidelines) relates to motor skill development in 3-4-year-olds. While guidelines to limit screen time exist, there is insufficient understanding of the real-world challenges parents face in meeting these recommendations. Few studies that have explored parental perspectives on the barriers and facilitators to adhering to screen time guideline have not examined the 3-4-year-olds specifically, but children as a whole.

This thesis aims to fill these key gaps by a) examining how both screen time and habitual sedentary behaviour relate to different domains of motor competence in 3- to 4-year-olds, contributing much-needed evidence on early childhood development b) utilising international data from the SUNRISE study to assess how objectively measured sedentary behaviour and adherence to sedentary behaviour guideline is associated with gross and fine motor skills and c) exploring parental perceptions of the barriers and facilitators to meeting screen time guidelines, providing valuable insights to inform the design of effective, family-focused interventions targeting screen time reduction in 3-4 year olds.

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Chapter 2: Associations between Sedentary Behaviour and Motor Competence in 3–4-year-olds

2. 1 Preface

The systematic review, "Associations between sedentary behaviour and motor competence in 3-4-year-olds", was published in the Journal of Motor Learning and Development in October 2024. The study aimed to summarise current literature which examined the associations between time spent in different types of sedentary behaviour (screen time, total objectively measured sedentary behaviour) and motor competence (fundamental motor skills, fine and gross motor skills, locomotor skills, ball skills and object control) in 3-4-year-olds. This preface aims to provide complementary details and justification of the methodology used in the review, which could not be included in the published manuscript due to the selected journal's word limit.

The systematic review was guided by Dr Xanne Janssen and Prof. John Reilly, with Nana Kwofie being the lead author. NK and XJ supported the synthesis of results, while NK and JJR assessed the quality (risk of bias) of the included studies. All authors supported the design of the systematic review, the methodology, revision and approval of the final manuscript submitted to the Journal of Motor Learning and Development for publication.

2.1.1 Introduction and Context

An initial research question was explored regarding children's sedentary behaviour and motor competence. This was identified by the research gaps highlighted in the introductory literature (Chapter 1), which emphasised sedentary behaviour as a key barrier to meeting the 24-hour movement guidelines in children under 5s and had a potential negative impact on children's motor skill acquisition. Hence, the systematic review aimed to test for associations of sedentary behaviour (screen time, total objectively measured sedentary behaviour) and the overall and individual components of motor competence (fundamental motor skills, fine and gross motor skills, locomotor skills, object control, balance) in 3- to 4-year-olds.

2.1.2 Literature Search and Inclusion

This systematic review followed the Preferred Reporting Item for Systematic Reviews (PRISMA) guideline (Page et al., 2021) in conducting and reporting findings from this review. Prior to commencing the search for the systematic review, authors searched for previous systematic reviews (as well as ongoing reviews) to ensure that the intended research question had not been answered. The review was registered with the International Prospective Register of Systematic Reviews PROSPERO, with the registration no CRD42021253381 in August 2021.

Using the PECO framework (population, exposure, comparisons, and outcome), authors identified key study concepts regarding inclusion and exclusion criteria for the review (Morgan et al., 2018). Search terms related to the research question were generated. Some terms used for the search included 'sedentary behaviour', 'gross motor skills', and 'preschoolers'. Boolean operators (AND, OR, NOT) were used to combine the search terms developed in the database search. Detailed information on the keywords used for the data search is presented in Table 1 below. Information on the inclusion and exclusion criteria for the process is reported in the manuscript presented in this chapter.

Table 1. Summary of Keywords and Combination used for the Database

	Keywords used for the database search
Population	"early childhood" or "preschool children" or "pre-school children" or "early years" or "children"
Exposure	"sedentary" or "sedentary behaviour" or "sedentary lifestyle" or "sedentary activities" or "physical inactivity" or "inactivity" or "screen time" or "screen based" or "sitting time" or "television time" or "screen-based entertainment" or "computer" or "video games" or "smartphone"
Outcomes	"Motor development" or "Motor Skill" or "motor competence" or "fundamental motor skill" or "motor proficiency" or "psychomotor performance" or "fine motor skill" or "gross motor skill" or "locomotor control" or "object control" or "child development" or "growth and development" or "ball skills" or "stability" or "balance"

2.1.3 Databases

A total of five online databases were thoroughly searched for articles on the 27th of July 2021 (with an updated search conducted on the 30th of September 2023) for studies that would be relevant for the review: Web of Science (core collection), PUBMED Central, EMBASE (Ovid), SPORT Discus and ERIC. These databases were used by the authors because they were most appropriate and key to the field of study (Bramer et al., 2017). The number of databases used was appropriate to ensure comprehensive and efficient coverage of the research topic and to increase the likelihood of relevant papers being included in the review. Ewald et al. (2022) also iterate that using two or more databases when conducting a systematic review improves coverage and decreases the risk of missing eligible papers (Ewald et al., 2022). All references retrieved from each database search were exported to the Rayyan software for screening by the authors. Rayyan is a user-friendly software app designed to support tasks related to title and abstract screening and the study selection process (Ouzzani, 2016). It also enables users to upload citations and full-text articles, create review projects, and collaborate on publicly available projects (Ouzzani et al., 2016). The use of this software simplified the screening process for authors.

2.1.4 Screening and Data Extraction

Screening of the articles used was done by two authors (NK and XJ) as stated in the published manuscript. This is in accordance with the recommendation of two or more screeners used during the systematic review screening process to help reduce the potential for missed studies (Stoll et al., 2019). Once the included articles were agreed on, one researcher (NK) conducted the data extraction, which was checked by a second researcher (XJ) for accuracy, in accordance with the standard practice for conducting a systematic review.

2.1.5 Quality Assessment of the Included Studies

Critical appraisals remain an important component of research, as they aim to assess the validity of data, completeness of reporting, methods and procedures, conclusion and compliance with ethical standards

(Porta, 2014). It is important for researchers to critically appraise the methodology used in studies to help determine confidence in the findings, as a weak design can introduce bias and lead to underestimation or overestimation of the findings (Higgins & Green, 2011).

The Joanna Briggs Institute (JBI) critical appraisal tool for cross-sectional and longitudinal studies was used to assess the quality of the included studies (Tufanaru et al., 2017). The authors adapted this tool because it offers a comprehensive framework for assessing the risk of bias in research studies, provides specific critical appraisal tools tailored to various study designs, and thus ensures a systematic and reliable evaluation of the methodological quality. Several other risk assessment tools could have been considered to assess the quality of the included studies in this review, such as the Cochrane Collaboration Risk of Bias Tool (CCRBT). This tool assesses six domains of bias, with several items assessed within each domain (Higgins & Green, 2011). Each domain is assigned a risk judgment of high, low, or unclear, which is combined to yield an overall risk grade of high, moderate, or low (Higgins & Green, 2011). However, this risk assessment tool was not appropriate for assessing the quality of studies in the present review, as it is used only to assess RCTs. Hence, the JBI tool was chosen as it provides a robust checklist for appraisal and assessment of most types of studies.

All papers selected for inclusion in the systematic review were subjected to rigorous appraisal by two critical reviewers (NK and JJR) in accordance with the JBI critical appraisal recommendations (JBI, 2017). The JBI critical appraisal tool for cross-sectional and longitudinal studies includes 8 and 11 questions, respectively, that address the internal validity and risk of bias of the study designs, particularly confounding, selection, and information bias, as well as the importance of transparent reporting. As mentioned in the published review, the questions were modified to include an additional question to address the issue of the sample sizes used in the included studies, i.e., an additional question assessed whether eligible studies considered sample size/ study power. This is due to the important role sample size plays in research reporting, as it is a significant determinant of the risk of false-negative findings (Biau et al., 2008). The modified JBI critical appraisal checklist tool for the included studies is found in Tables 5 and 6 of the published paper.

2.1.6 Analysis

Details of the analysis used are presented in the synthesis of results section in the published review. The authors adapted the method of vote counting to synthesise the results, in accordance with the Cochrane Handbook for Systematic Reviews of Interventions (McKenzie & Brennan, 2019). This method can be used to summarise and analyse evidence, especially when numerical data is sparse, inconsistent, or unavailable. The vote-counting approach focuses on comparing the number of effects showing benefit (positive results) to the number of effects showing harm (negative results) for a particular outcome. With this method of analysis, neither statistical significance nor the size of the effect is considered in the categorisation (McKenzie & Brennan, 2019).

2.1.7 Data Reporting Standards

Two of the included studies (Chaibal et al., 2022; Wang et al., 2020) did not report a direction of association with the exposure and hence were not included in the vote counting results tables. As the vote-counting approach requires clear identification of the direction of effect to classify associations as positive, negative, or null, these studies could not be meaningfully included in the synthesis due to the lack of association. This highlights a broader limitation within the current evidence base, where inconsistent reporting of effect estimates, confidence intervals, or domain-specific outcomes limits the ability of systematic reviews to fully synthesise available data. It is therefore important that future studies adhere to transparent reporting standards, including the reporting of effect sizes and direction of associations for specific outcome domains, to strengthen future evidence synthesis and also allow for a more robust conclusions regarding the relationship between sedentary behaviour and motor competence. These studies could not be meaningfully included in the synthesis due to the lack OF missing information on the size or direction of effect.

2.1.8 Literature Update

Since the completion of the systematic review search in September 2023, several studies examining sedentary behaviour, screen exposure, and developmental outcomes in early childhood have been

published. Recent research continues to highlight potential associations between screen use and developmental indicators in preschool children. For example, a recent cross-sectional study by Gomes et al. (2024) examining screen exposure among four-year-old children reported that high prevalence of inadequate screen time was associated with a lower score in motor development and increased the habit of eating in front of screens. (Gomes et al., 2024). Another cross sectional study by Chen et al. (2024) which used objective or digital monitoring approach to examine how different types of screen content and exposure patterns relate to developmental outcomes, provided evidence that suggest that exposure to certain types of non-educational or fast-paced media may be associated with lower gross and fine motor development scores (Chen et al., 2024).

Another recent contribution to this research field is a study by Draper et al. (2024) on building early investments for the health and development of young children published in The Lancet. This paper highlights that the period from 2 to 5 years is a critical window for establishing healthy behavioural patterns, with child development shaped by multiple interacting influences across home, education, and community environments (Draper et al., 2024). Within this framework, sedentary behaviour (such as screen time), was increasingly recognised as key, interrelated determinants of early childhood health and developmental trajectories.

Collectively, these recent studies reinforce the growing body of evidence suggesting that sedentary behaviour and screen exposure remain important factors influencing developmental outcomes in early childhood and support the continued relevance of examining these behaviours in relation to motor competence.

2.1.8 Conclusion

The preface section of this chapter aimed to provide additional details on the rationale and justification for the methods used for the published systematic review, which will now be presented exactly as it appears in the published journal.

Manuscript 1: Associations between sedentary behaviour and motor competence in 3-4-year-olds- a systematic review

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2.2 Abstract

BACKGROUND: Several studies have reported low adherence to World Health Organisation sedentary behaviour guidelines in the early years. The purpose of this review is to examine the associations between time spent in different types of sedentary behaviour (screen time, habitual sedentary behaviour) and motor competence (fundamental motor skills, fine and gross motor skills, locomotor skills, object control and balance) in 3-4-year-olds.

METHODS: Five databases were searched on the 27th of July 2021, with an updated search conducted on the 30th of September 2023: Web of Science (core collection), PubMed Central, EMBASE (Ovid), SPORTDiscus, and ERIC. Studies were included in the review if they reported on an association between time spent in sedentary behaviour at ages 3-4 years and motor competence. The methodological quality of each included study was assessed using the Joanna Briggs Institute Critical Appraisal Tools. Vote counting was used to determine the direction of associations.

RESULTS: Of 5276 total studies found in the search, 16 studies (12 cross-sectional, 4 longitudinal) from 11 different countries met the inclusion criteria. Seven studies examined the association between screen time and motor competence, six examined the association between time spent in sedentary behaviour and motor competence, and three examined the association between both screen time and time spent in sedentary behaviour and motor competence. The direction of associations was predominantly negative for both screen time and time spent in habitual sedentary behaviour with different components of motor competence. Quality of evidence ranged from 3-7 out of 9 for cross-sectional studies and 6-9 out of 12 for longitudinal studies.

CONCLUSION: There may be negative associations between time spent sedentary and motor competence in 3–4-year-olds. However, future studies with stronger study designs are required to confirm these associations. Findings from this review should be considered when designing strategies and interventions to promote adherence to sedentary behaviour guidelines.

Keywords: screen time, accelerometer, early years, motor development, motor skills

Associations between Sedentary Behaviour and Motor Competence in 3-4-Year-olds

2.3 Background

The World Health Organization (WHO) has identified the early years as a critical time to intervene to improve child health and development, and highlights physical activity, sleep and sedentary behaviour (SB) as key behaviours which should be targeted (WHO, 2018; WHO, 2019). Sedentary behaviour, usually defined as energy expenditure ≤ 1.5 metabolic equivalents (MET) while sitting or lying down during the waking period (Bames et al, 2012), in excess poses a health concern across all age groups (Tremblay et al., 2017; Davey, 2014; Kohl et al., 2012; Kuzik et al, 2017; Moore et al, 2017). For SB, WHO recommends no more than 60 minutes of sedentary screen time and restraint for no more than an hour at a time (e.g., highchair, prams/strollers) in a 24-hour period for 3-4-year-olds (WHO, 2019). Some studies have shown levels of screen time among young children to be typically more than 3 hours a day, especially during the Covid-19 pandemic lockdown period (Webster et al., 2019; Moore et al., 2020; Madigan et al., 2022; Neville et al., 2022). High levels of SB may negatively impact a range of health outcomes, including motor competence (MC) (Santos et al., 2021). Motor competence, which is an individual's degree of proficient performance in a broad range of motor skills, is a crucial part of a young child's development and has been considered a foundation for physical activity in young children (Utesch et al., 2019). Under the umbrella concept of MC, different terms and concepts such as fundamental motor or movement skills, motor proficiency, motor coordination, motor ability, fine and gross motor skills have been used in the literature (Utesch et al., 2019). One misconception is that children will attain typical levels of MC naturally as they get older, but many children do not (Goodway & Branta, 2003; Goodway et al., 2003; Williams et al., 1991). Considering the importance of developing MC in children, it is therefore important to examine SB as a factor that can potentially affect MC in early childhood.

Poitras et al. (2017) reviewed the relationship between SB and health indicators, including MC, in the early years. Studies up until April 2016 were included and results from that systematic review showed

null associations with SB and MC - only 7 eligible papers were identified and the quality of evidence of the included studies was very low. However, since the publication of that review, there has been an increased interest in research in the area of SB, with more publications emerging that focus on the early years' population, partly due to the growing awareness that early life behaviours may influence future health outcomes and the release of the WHO guidelines in 2019 (Hidding et al., 2017). Hence, an update on the review by Poitras et al. (2017) to look at more recent evidence and examine associations will be timely. A systematic review by Dos Santos et al. (2019) found negative associations between time spent in SB and MC. However, this review did not examine the associations between different types of SB and MC separately, nor did it analyse individual MC subcomponents, such as locomotor skills, object control, and balance. Dos Santos et al. (2019) also considered children aged 3-6 years as a single category, which is not in line with the age group for the 24-hour movement guidelines by the WHO (3-4 years) (WHO, 2019). An updated review is therefore required to investigate relationships between different types of SB, such as screen time and habitual SB (any activity taking place in a seated or reclining posture with an energy expenditure ≤1.5 metabolic equivalents of task (MET) while awake), and different components of MC among 3- and 4-year-olds. Therefore, the aim of this study is to examine associations between both screen time and habitual SB, and their association with different components of MC (fundamental motor skills, fine and gross motor skills, locomotor skills, object control and balance) in 3- to 4-year-olds.

2.4 Methods

2.4.1 Protocol and Registration

This systematic review followed the Preferred Reporting Item for Systematic Reviews (PRISMA) guideline (Page et al., 2021). This systematic review is registered with the International Prospective Register of Systematic Reviews PROSPERO, with registration no CRD42021253381.

2.4.2 Study Inclusion Criteria

This systematic review used the PECO framework (population, exposure, comparisons, and outcome) to identify key study concepts for the research question (Morgan et al.,2018) (See table 1).

Table 1. Inclusion and Exclusion Criteria Table

	Inclusion	**Exclusion**
Age	Children between 3.00 and 4.99 years	Children less than 3.00 and older than 4.99 years
Sex	Both male and female	
Health	Children without any health conditions	Children with medical conditions
Publication date	Articles published from April 2016	Articles published before April 2016
Language	English language	Non-English language
Exposure/outcome	Articles that report on associations between screen time/sedentary behaviour and motor competencies	Articles that do not report on associations between screen time/sedentary behaviour and motor competencies

2.4.3 Population

Articles reporting on children who were considered healthy between the ages of 3.0 and 4.9 years were included in this review. This age group definition is in line with the WHO guidelines on the 24-hour movement behaviours for 3.0-4.9-year-olds (WHO, 2019). Articles that reported on children between

the ages of 3 and 4.9 years with diseases or existing health conditions that could potentially affect the outcome were excluded from the review. Also, articles which reported on a sample of children with a mean age below 3.0 or above 4.9 years were excluded unless sub-analysis results were provided for those 3.0-4.9 years of age.

2.4.5 Exposure

The exposure was a measure of usual (habitual) time spent sedentary (sitting or lying down) and/or on a screen (e.g., television time, time spent on mobile devices, sitting time, video gaming). Different types of screen time were classified as one category for this review. Studies that used either objective (e.g., accelerometer) and/or subjective measures (e.g., parent questionnaire, diaries) of SB were included. For this review, SB was defined as any waking behaviour characterised by an energy expenditure of ≤1.5 METs while in a sitting or reclining posture (Tremblay et al, 2011). Studies that defined SB based on low levels of physical activities, i.e. 'physical inactivity', were not included.

2.4.6 Comparison

If studies reported on various durations, interruptions, patterns, and types of sedentary behaviour, these were used for comparison.

2.4.7 Outcome

The primary health outcome for this review is MC which includes fundamental motor skills which is "building blocks" for more advanced and complex movements, gross motor skills (like pushing, pulling), fine motor skills (like raising hands), locomotor skills (such as hopping, leaping, galloping), object control (throwing, catching, dribbling) skills and balance (Utesch et al., 2019). Studies that measured any form of motor competence as an outcome with the use of subjective measures, such as the Ages and Stages questionnaire or the Movement Assessment Battery for children, were included. Cross-sectional, longitudinal, intervention, or experimental study designs that met the above inclusion criteria and were published in English after April 2016 were included in the review.

2.4.8 Information Sources and Search Strategy

An electronic literature search was conducted on the following databases on the 27th of July 2021 (with an updated search conducted on 30th September 2023): Web of Science core collection, PUBMED Central, EMBASE (Ovid), SPORTDiscus and ERIC. The search period was set between April 2016 and September 2022. The search period started from when the previous review by Poitras ended. The full search strategy can be found in Appendix A. Example keywords used for the population search included early childhood, preschool children; for the exposure search, sedentary behaviour, screen time, sitting time, and for the outcome search, motor competence, fine motor skill, gross motor skill. Search results for each database were exported to EndNote Reference Manager (Version X9), and duplicates were removed.

2.4.9 Data Screening

NK and XJ independently screened the titles and abstracts of all articles. If articles were deemed to meet the inclusion criteria, full-text copies were obtained. Full-text screening was performed independently by the same reviewers. In cases of conflict between two reviewers, inclusion was decided by discussion between the reviewers, or, if needed, a third reviewer (JJR) was consulted.

2.4.10 Data Extraction

Data extraction was completed by NK and verified by XJ for accuracy. Data was extracted into a predefined Microsoft Excel spreadsheet. A study ID was given to each included study. The extracted information included the study and participant characteristics (i.e., study design, country, sample size, gender), exposure details (SB and screen time description and measure), outcome details (MC description and measure) and key findings with respect to the association of sedentary behaviour or screen time with MC (including any covariates included in the analysis). A p-value of <0.05 was used to denote statistically significant findings.

2.4.11 Quality Assessment for Included Studies.

Quality of eligible studies was assessed independently by two reviewers (NK and JJR). The Joanna Briggs Institute (JBI) critical appraisal tools were used as appropriate for each study based on the study design (Tufanaru et al., 2017). The JBI checklist was modified slightly- questions which referred to the standard criteria used for the measurement of the condition (disease), and whether participants were free from the outcome (disease) at the start of the study, were not applicable to the review, hence, were not used in the assessment (see supplementary file 2). However, a question was added by the authors to provide an assessment of the sample sizes used in the included studies, i.e., we assessed whether eligible studies considered sample size/study power. Each category in the JBI assessment received a one if the criterion was met and a zero if it was not. The sum of all categories was then calculated to create a total quality assessment score. The higher the score, the higher the quality of the study. The adapted JBI critical appraisal checklist tool for the included studies is found in supplementary files 2 and 3.

2.4.12 Synthesis of Results

Due to the heterogeneity of the included studies, a meta-analysis could not be conducted. This was due, for example, to the differences in the measurement tools used in both the exposure and outcome measures, as well as differences in statistical analysis reported (e.g., beta coefficients, odds ratios, Pearson correlation coefficients). Instead, the vote-counting method based on the direction of association was performed in line with the Cochrane Handbook for Systematic Reviews of Interventions (McKenzie & Brennan, 2019). Associations were classified as positive associations where the exposure measure (screen time or habitual SB) was associated with higher or improved MC, while associations were classified as negative if the exposure measure was associated with a lower MC (e.g., higher screen time associated with decreased MC). Results were summarised separately for the two exposure measures (screen time and habitual SB). The summary results were presented as the number of associations found divided by the total number of studies included. A binomial probability test was performed; the p-value of this test indicates the probability of observing the summary results if the exposure outcome associations were in the opposite direction (McKenzie & Brennan, 2019). This means

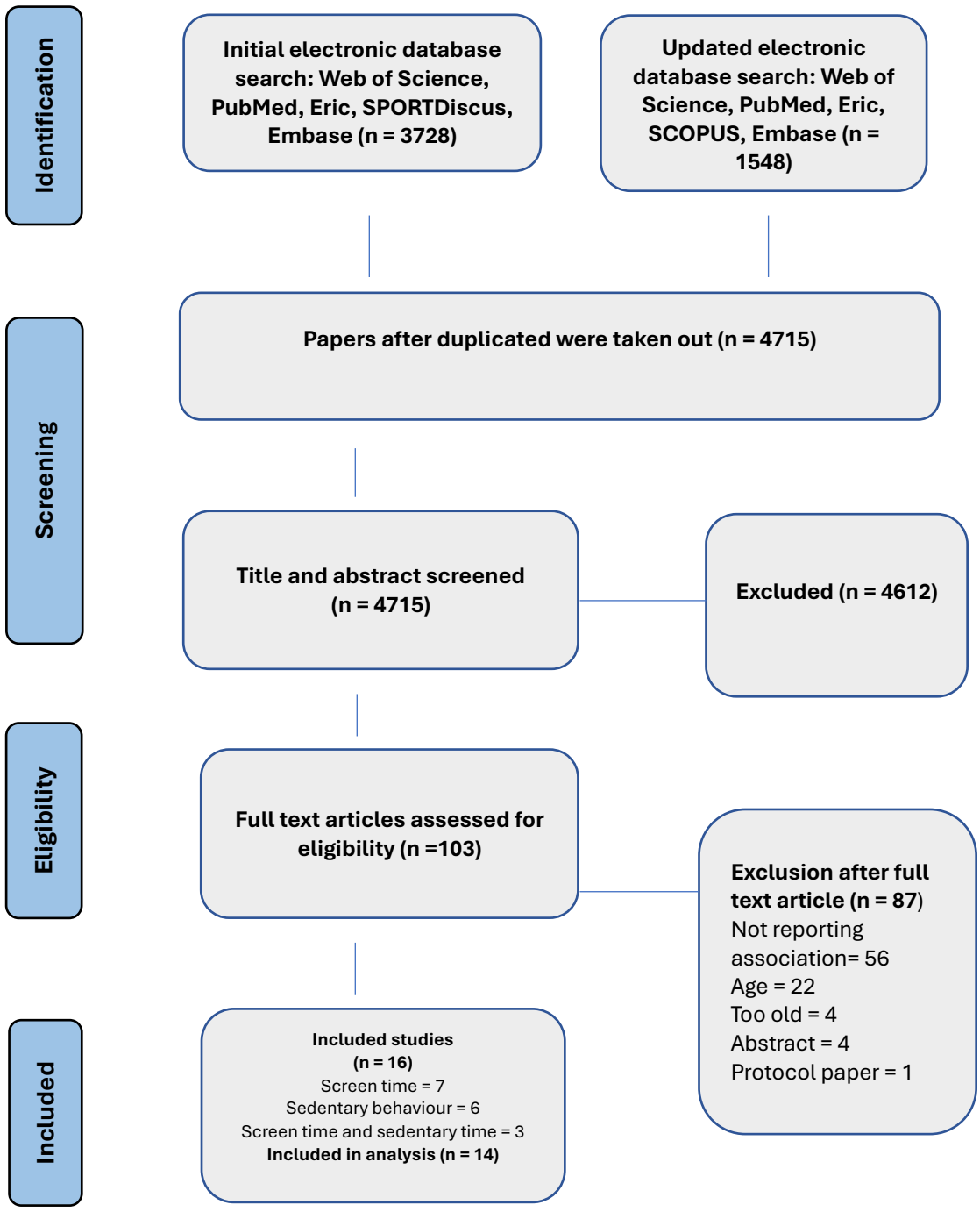
the smaller the p-value, the higher the chances of the results being valid, independent of the p-values reported by the authors of the included studies.

2.5 Results

2.5.1 Description of Studies

The database search yielded a total of 5276 studies, of which 561 duplicates were removed. After screening of titles and abstracts, 103 studies remained for full-text screening. Following the full-text screening, 16 studies were included in the final review (Figure 1). Excluded papers were studies that did not report on relevant associations (n = 56), included participants outside the age range (n = 22), were published outside the search time period (n = 4), were abstracts (n = 4) or a protocol paper (n = 1). Of the 16 included studies, 2 studies were longitudinal studies (Caredot et al., 2018; Wang et al., 2020), and 12 studies were cross-sectional (Webster et al., 2019; Moon et al., 2019; Zheng et al., 2021; Chaibal et al., 2022; Yu et al., 2022; Mota et al., 2020; Nilsen et al., 2020b; Roscoe et al., 2021; Kim et al., 2021; Li et al., 2022; Haugland et al., 2023; das Virgens et al., 2023) with two studies reporting both cross-sectional and longitudinal results (Kracht et al., 2020; Nilsen et al., 2020a). Six studies reported on time spent in habitual SB (Mota et al., 2020; Nilsen et al., 2020a; Nilsen et al., 2020b; Wang et al., 2020; Roscoe et al., 2021; Haugland et al., 2023) as measured by accelerometer, seven studies reported on screen time (Caredot et al., 2018; Kracht et al., 2020; Moon et al., 2019; Zheng et al., 2021; Chaibal et al., 2022; Yu et al., 2022; Li et al., 2022) as reported by parents using questionnaires and three studies reported on both SB and screen time (Webster et al., 2019; Kim et al., 2021; das Virgens et al., 2023). A summary of the selection and screening process is shown in the PRISMA flow diagram (Figure 1). Two of the included studies (Chaibal et al., 2022; Wang et al., 2020) did not report a direction of association with the exposure and hence were not included in the vote counting results tables. One study (Webster et al., 2019) did not report a direction of association with habitual SB and balance, locomotor skills and object control skills subscales and hence was not included in the summary table.

Fig 1. PRISMA Flow Diagram of Search and Screening Stages



2.5.2 Participants

The study samples for the 16 included studies included both boys and girls (total of 7,427 participants) from a range of different countries (see Table 2).

Table 2. Descriptive Characteristics of Included Studies.

Reference ID	Country	Study Design	Sample Size	Sample Age (mean ± Standard Deviations)	Exposures	Outcomes
Screen time measure						
Cardoret et al. (2018)	Canada	Longitudinal (base measurement at age 4, follow up at age 7)	N= 113 (boys =51, girls = 62)	4, 5 and 7 years* (no mean age reported)	Screen time: Presence or absence of television, video games, or computers; measured hours per week	Fine and gross motor skills; measured with the Short Form of the BOT-2 (SF)
Chaibal & Chaiyakul, 2022)	Thailand	Cross-sectional	N= 85_(boys =43, girls = 42)	2-5 years* (Mean= 4.05, SD= 0.91)	Screen time (Smart phone and tablet usage), measured minutes per day via parent reported questionnaire	Gross and fine motor skills using the Denver Developmental Screening Test (Denver II)
Kracht et al. (2020).	USA	Cross-sectional, Longitudinal (one year follow up)	N (cross-sectional) = 107 (boys = 48, girls = 59); N (longitudinal) = 53 (boys = 28, girls = 25)	Cross-sectional- Mean age 3.4years (SD= 0.6) Longitudinal- Mean age 3.2 (SD= 0.5)	Screen time: time spent using or viewing television, computer games, video games, smartphones, and tablets; measured in hours per day.	Ball skills, locomotor, Total fundamental movement skills; measured with the Test of Gross Motor Development-3rd edition questionnaire

Reference ID	Country	Study Design	Sample Size	Sample Age (mean ± Standard Deviations)	Exposures	Outcomes
Li et al. (2022).	China	Cross-sectional	N = 322 (boys=181, girls= 141)	3-6 years* (Mean age for boys= 4.74, SD= 0.89; Mean age for girls= 4.63, SD=0.83)	Screen time is measured with a parent questionnaire in hours per day.	Fundamental motor skill (object control skill and locomotor) measured using the Test of Gross Motor Development (Third edition)
Moon et al. (2019).	South Korea	Cross-sectional	N = 117 (boys = 63, girls = 54)	Mean age 4.5 (SD = 0.9 years)	Screen time: smart device usage frequency, smart device usage time, appropriate smart device usage level; smart devices considered-smartphones and tablet computers; measured hours per day	Fine and gross motor skills (measuring tool not reported).
Yu et al. (2022).	Taiwan	Cross-sectional	N = 2139	3.0 years (Mean and SD not reported)	Screen time measurement (smartphone, tablet, personal computer, laptop, video game console, television, or none) using the parent questionnaire reported in hours per day	Gross and fine motor skills were assessed using the KIT-M36 questionnaire.
Zheng et al. (2021).	China	Cross-sectional	N = 877 (boys = 463, girls = 414)	Age 3-5 years (Mean age 4.6 years, SD not reported)	Screen time (digital device): the daily time spent using a digital device; measured mins per day.	Fine and gross motor skills; measured with the Hong Kong Early Child Development Scale (HKECDS) (for fine motor

Reference ID	Country	Study Design	Sample Size	Sample Age (mean ± Standard Deviations)	Exposures	Outcomes
						skill) and the Movement Assessment Battery (for gross motor skills).
Habitual Sedentary Time Measure						
Haugland et al. (2023).	Norway	cross sectional	N= 952 (51% boys, 49% girls)	3-5* years (mean age 4.3, SD 0.9)	Sedentary time (SED) was measured using the ActiGraph GT3X+ with a cut-off ≤100 cpm, measured in mins per day.	FMS (locomotor, object control and/or balance skills) was measured using the test of Gross Motor Development 3 (TGMD-3) and the Pre-schoolers Gross Motor Quality Scale (PGMQS).
Mota et al. (2020).	Brazil	Cross-sectional	N = 204 (boys = 101, girls = 103)	Mean age 4.5 years, SD= 0.8	Total Sedentary Behaviour: ActiGraph wGT3X, SB estimated using the 819 counts/15s cut point using vector magnitude; measured mins per day.	Ball skills, locomotor, fundamental movement skills; measured with the Test of Gross Motor Development-2nd edition questionnaire

Reference ID	Country	Study Design	Sample Size	Sample Age (mean ± Standard Deviations)	Exposures	Outcomes
Nilsen et al. (2020a).	Norway	Cross-sectional, Longitudinal (two year follow up)	N = (Cross-sectional) = 376; N (Longitudinal) = 376	Cross-sectional -mean age 4.7 years, SD= 0.9 Longitudinal- mean age 6.4 years, SD= 0.9	Total Sedentary Behaviour: ActiGraph GT3X+ SB calculated as SED ≤ 100 cpm; measured mins per day.	Locomotor, object control, balance; measured with Test of Gross Motor Development-3rd edition questionnaire and the Pre-schooler Gross Motor Quality Scale
Nilsen et al. (2020b).	Norway	Cross-sectional	N = 1081 (boys = 562, girls = 519)	Mean age 4.7 years, SD= 0.09	Total Sedentary Behaviour: ActiGraph wGT3X, SB calculated as SED ≤ 100 cpm; measured mins per day.	Locomotor, object control, balance; measured with Test of Gross Motor Development-3rd edition questionnaire and Pre-schooler Gross Motor Quality Scale

Reference ID	Country	Study Design	Sample Size	Sample Age (mean ± Standard Deviations)	Exposures	Outcomes
Roscoe et al. (2021).	England	Cross-sectional	N= 185 (boys = 99, girls = 86)	3-4 years (mean age and SD not reported)	Total sedentary behaviour using the GENEActiv waveform triaxial accelerometer (ActivInsights Ltd., Cambridge, UK), cut off <5.3 cpm for SB measured hours per day.	Fundamental motor skills; measured with the Test of Gross Motor Development-2 (TGMD-2)
Wang et al. (2020).	China	Longitudinal	N = 268 (boys = 126, girls =142)	3-6 years*(Mean age and SD not reported)	Total Sedentary Behaviour: ActiGraph wGT3X, SB estimated using the 819 counts/15s cut point; measured hours per week.	Balance, measured with the Test of Gross Motor Development, third edition (TGMD-3)
Screen Time and Habitual Sedentary Time Measure						
Kim et al. (2021).	Vietnam	Cross-sectional	N = 103	3-4 years (mean age 4.12, SD 0.44)	Total Sedentary Behaviour: ActiGraph GT3X+ accelerometer. SB calculated as using the cut-off 0–199, measured mins per day. Screen time spent using electronic devices like smartphone, tablets, video game) was reported using parent questionnaire in hours and minutes per day.	Gross and fine motor skills were assessed and scored using activities in the Ages and Stages Questionnaire (3rd edition)

Reference ID	Country	Study Design	Sample Size	Sample Age (mean ± Standard Deviations)	Exposures	Outcomes
Virgen chagas et al. (2023)	Australia	Cross-sectional	N = 372 (for screen time)	Age 3.5 and 5* years; N= 188 (for total sedentary time)	Total Sedentary Behaviour: ActiGraph GT1M accelerometer. SB calculated as using the cut-off 0–199, measured mins per day. Screen time was time spent watching TV/DVDs, playing on the computer/electronic games, and playing handheld electronic games was reported using parent questionnaire in hours and minutes per day	Motor competence (object control and locomotor) measured using the Test of Gross Motor Development (Second Edition)
Webster et al. (2019)	USA	Cross-sectional	N = 126 (boys = 58, girls =68)	3-4 years (Mean age 3.4, SD 0.5 years)	Screen time and Total Sedentary Behaviour: ActiGraph GT3X+SB calculated using the 799 counts/60s cut point; measured hours per week.	Fundamental motor skills; measured with the Test of Gross Motor Development-3rdedition (TGMD-3) and Movement Assessment Battery for Children-2nd edition (MABC-2).

SB= sedentary behaviour; ST= screen time; MC= motor competence; * analysis included participants within 3-4 years

2.5.3 Screen Time

Associations between screen time and MC were examined in 10 of the included studies (Table 3). Of these 10, one was a longitudinal study (Caredot et al., 2018), 8 were cross-sectional (Moon et al., 2019; Zheng et al., 2021; Chaibal & Chaiyakul, 2022; Yu et al., 2022; Li et al., 2022; Webster et al., 2019; Kim et al., 2021; Virgen Chagas et al., 2023), and 1 used both longitudinal and cross-sectional data (Kracht et al., 2020). Screen time measures included parent-reported questionnaires to report time spent on tv, video games, computer games, smart phone/device usage, tablets and computers which were expressed in minutes per day, hours per day and hours per week. Outcome measures included fundamental motor skills, gross and fine motor skill, locomotor skill, object control skills, measured with the Test of Gross Motor Development 2nd and 3rd edition, the Short Form of the BOT-2 SF, the Hong Kong Early Child Development Scale (HKECDS) (for fine motor skill), the Movement Assessment Battery (second edition) and the Denver Developmental Screening Test (Denver II).

Mixed results were reported for fundamental motor skills (4 out of 5 negative associations; binomial probability test: p=0.19), gross motor skills (4 out of 6 negative associations; binomial probability test p=0.34), fine motor skills (6 out of 7 negative associations; binomial probability test p=0.06), locomotor skills (2 out of 4 negative associations; binomial probability test p=0.69) and object control skills (3 out of 4 negative associations; binomial probability test p=0.31). Two longitudinal studies found a negative association with fundamental motor skills (Caredot et al., 2018; Kracht et al., 2020), and one with locomotor skills (Kracht et al., 2020) and object-control skills (Kracht et al., 2020). For cross sectional studies, there were negative associations with fundamental motor skills (Webster et al., 2019; Yu et al., 2022), gross motor skill (Moon et al., 2019; Zheng et al., 2021; Yu et al., 2022; Kim et al., 2021), fine motor skills (Webster et al., 2019; Moon et al., 2019; Zheng et al., 2021; Yu et al., 2022; Kim et al., 2021), locomotor skills (das Virgens et al., 2023) and object control skills (Kracht et al., 2020; Li et al., 2022). Significant associations in individual studies were only found in those studies reporting negative associations between screen time and the measured MC outcome (Webster et al., 2019; Caredot et al., 2018; Kracht et al., 2020; Zheng et al., 2021; Yu et al., 2022).

Table 3. Summary Table of Exposure (Screen Time) and Outcome Associations

Exposure: Screen Time				
Outcome	**Associations in included studies**	**Summary**		**N participants (Total or range)**
		n/N (%)	**P value**	
Fundamental motor skills	- - - - +	4/5 (80)	0.19	Cross-sectional (107-126); longitudinal (53)
Gross motor skill	-[a]- - - + +[b]	4/6 (67)	0.34	Cross-sectional (877- 926)
Fine motor skills	- -[a] -[b] - - - +	6/7 (86)	0.06	cross sectional (877)
Locomotor skill	- - + +	2/4 (50)	0.69	Cross-sectional (107-372) Longitudinal (53)
Object control	- - - +	3/4 (75)	0.31	Cross-sectional (107-372) Longitudinal (53)

n = number of negative associations; N = total number of associations for the exposure outcome relation. Studies that found significant associations in bold.

Longitudinal studies in italics. [a] Negative association in 3-year-olds with exposure, [b] positive association in 4-year-olds with exposure

2.5.4 Habitual Sedentary Behaviour

Associations between time spent in SB and MC were examined in 9 of the included studies (Table 4). Of these 9 studies 1 was longitudinal (Wang et al., 2020), 7 were cross-sectional data (Mota et al., 2020; Nilsen et al., 2020a; Nilsen et al., 2020b; Roscoe et al., 2021; Haugland et al., 2023; Webster et al., 2019; Kim et al., 2021), and 1 used both longitudinal and cross-sectional data (Virgen Chagas et al., 2023). Habitual SB was measured using the ActiGraph GT3X+ and the GENEActiv waveform triaxial accelerometer. SB was reported as minutes per day and hours per day. Outcome measures included fundamental motor skills, gross and fine motor skills, locomotor skills, object control skills and balance, measured with the Test of Gross Motor Development questionnaire 2nd and 3rd edition), the Movement Assessment Battery for Children-2nd edition (MABC-2) and the Pre-schooler Gross Motor Quality Scale.

Negative associations were reported for balance (4 out of 4 negative associations; binomial probability test p=0.06). Mixed associations were reported for fundamental motor skills (4 out of 8 negative associations; binomial probability test p=0.66), locomotor skills (10 out of 13 negative associations; binomial probability test p=0.05), and object control skills (9 out of 13 negative associations; binomial probability test p=0.13). For habitual SB time, longitudinal studies found a negative association with locomotor skills (Nilsen et al., 2020a), object control skills (Nilsen et al., 2020a), and balance (Nilsen et al., 2020a). For cross sectional studies, there were negative associations with fundamental motor skills (Mota et al., 2020; Roscoe et a., 2021), locomotor skills (Mota et al., 2020; Nilsen et al., 2020b; Nilsen et al., 2020b; Roscoe et al., 2021; Haugland et al., 2023; das Virgens et al., 2023), object control skills (Mota et al., 2020; Nilsen et al., 2020b; Nilsen et al., 2020b; Roscoe et al., 2021; Haugland et al., 2023; das Virgens et al., 2023) and balance (Nilsen et al., 2020b; Nilsen et al., 2020; Haugland et al., 2023). Significant associations in individual studies were found in those studies reporting both negative (Nilsen et al., 2020a; Nilsen et al., 2020b; Roscoe et al., 2021) and positive (Mota et al., 2020; Roscoe et al., 2021) associations between SB and the measured MC outcome.

Table 4. Summary Table of Exposure (Sedentary Behaviour) and Outcome Associations

Exposure: Habitual Sedentary Behaviour				
Outcome	**Associations in included studies**	**Summary**		**N participants (Total or range)**
		n/N (%)	**P value**	
Fundamental motor skills	-[a] -[a] -[a] -[b] +[b] +[a] +[a] +[b]	4/8 (50)	0.66	Cross-sectional (185-204)
Locomotor skill	-[a] -[a] -[a] -[b] - [b]- - - - - +[b] +[a] +[b]	10/13 (73)	0.05	Cross-sectional (185-1081), longitudinal (224)
Object control	-[a] -[a] -[b] -[b] - - - - - +[b] +[a] +[a] +[a]	9/13 (64)	0.13	Cross-sectional (185-1081) longitudinal (224)
Balance	- - - -	4/4 (100)	0.06	Cross-sectional (217-1081) longitudinal (224)

n = number of negative associations; N = total number of associations for the exposure outcome relation. Studies that found significant associations in bold. *Longitudinal studies in italics.* [a] Sedentary behaviour is replaced with moderate-to-vigorous physical activity; [b] sedentary behaviour is replaced by sleep or light physical activity

2.5.5 Quality Assessment

The overall quality of evidence for the study scores ranged from 3 to 7 (out of a potential 8) for the cross-sectional studies and 6 to 9 (out of potential 12) for the longitudinal studies (Tables 4 and 5). The main source of potential bias was sample size. No study provided a justification for the sample size used for the research. Another source of bias included missing information on the validity and reliability of some of the measurement tools used for the exposure variables (sedentary behaviour, including screen time). Quality assessment for longitudinal and cross-sectional studies is shown in Tables 5 and 6.

Table 5. Quality Assessment of Included Cross-sectional Studies

Study	Inclusion criteria	Subjects and setting detailed	Valid/reliable exposure measure	Measure of condition	Confounding factors identified	Strategy for confounding factors stated	Valid/reliable outcome measure	Appropriate statistical analysis	Adequate sample size	Total Score
Chaibal & Chaiyakul. (2022)	Y	Y	N	N/A	Y	Y	Y	Y	N	6
Haugland et al. (2023)	Y	Y	Y	N/A	Y	Y	Y	Y	N	7
Kim et al. (2021)	Y	Y	U	N/A	Y	Y	Y	Y	N	6
Li et al. (2022)	Y	Y	U*	N/A	Y	Y	Y	Y	N	6
Moon et al. (2019)	Y	Y	U	N/A	N	N	U	Y	N	3
Mota et al. (2020)	Y	Y	Y	N/A	U	U	Y	Y	N	5
Roscoe et al. (2021)	Y	Y	U	N/A	U	U	Y	Y	N	4
Virgen Chagas et al. (2023)	Y	Y	U	N/A	U	U	Y	Y	N	4
Wang et al. (2020)	Y	Y	Y	N/A	U	U	Y	Y	N	5
Webster et al. (2019)	Y	Y	U	N/A	Y	Y	Y	Y	N	6
Yu et al. (2022)	Y	Y	N	N/A	U	U	N	U	Y	3
Zheng et al. (2021).	Y	Y	U	N/A	Y	Y	Y	Y	N	6

Y = Yes, U = unclear, N = No, N/A = Not applicable, U*= accelerometery measure valid and reliable, parent questionnaire unclear of validity/reliability.

Table 6. Quality Assessment of Included Longitudinal Studies

Study	Inclusion criteria	Measure	validity and reliability of exposure	Confounding factors identified	Strategy for confounding factors stated	participants free from outcome	validity and reliability of outcome measure	Reported follow up	follow up described and explored	strategies for incomplete follow ups	appropriate statistical analysis	sample size	Total score
Cardoret et al. (2018)	Y	Y	Y	N	N	N/A	Y	Y	U	U	Y	N	**6**
Kracht et al. (2020)	Y	Y	U	Y	Y	N/A	Y	Y	N	N	Y	N	**7**
Nilsen et al. (2020)	Y	Y	Y	Y	Y	N/A	Y	Y	Y	N	Y	N	**9**
Nilsen et al. (2020)	Y	Y	Y	Y	Y	N/A	Y	Y	N	N	Y	N	**8**

Y = Yes, U = unclear, N = No, N/A = Not applicable

2.6 Discussion

The purpose of this study was to conduct a systematic review of recent studies to examine the associations between time spent in different components of both SB (screen time and habitual SB) and MC (fundamental motor skills, fine and gross motor skills, locomotor skills, ball skills/object control and balance) among 3-4-year-olds. For this review, screen time was time spent on electronic devices (watching tv, video games, time spent on tablets/phones) which was generally reported via parent questionnaire, while habitual SB was any activity in a seated or reclining posture with an energy expenditure ≤1.5 metabolic equivalents of task (MET) while awake (e.g., sitting, lying, time spent in a buggy) and was generally measured with the use of an ActiGraph accelerometer.

With regards to screen time, findings showed a predominantly negative association with fundamental motor skills, gross motor skills, fine motor skills and object control skills, which may indicate that children with high screen time levels may perform poorer on the motor competence measurement scales. For habitual SB, findings also showed a predominantly negative association with locomotor skills, object control skills and balance, which may suggest that children who accumulate more time on habitual SB performed poorer on the motor competence measurement scales. These associations however did not show a statistical significance which may partly be due to fewer studies used for the analysis, which highlights a limitation with the analytical method used. With the method of vote counting, a binomial probability test was conducted; however, the power of the binomial probability test is lower when the number of included studies is small.

For associations between screen time and MC, findings from this review expand on the previous review by Poitras et al. (2017), which found TV time to be negatively associated with motor skill development, with findings concluding that associations between screen time and MC were largely unfavourable/null.

For associations between habitual SB and motor competence, findings from this review also support findings from previous reviews by Dos Santos et al. (2021) and Poitras et al. (2017), both of which showed unfavourable associations between time spent in SB and MC among children between 3 and 4 years old (Dos Santos et al., 2021; Poitras et al., 2017).

Research has reported that between 17% and 50% of pre-schoolers between the ages of 3 and 4 years adhere to the WHO SB guidelines (Carson et al., 2019; Cliff et al., 2017; De Craemer et al., 2018), and excess sedentary screen time may reduce time spent on physical activity and/or sleep in the majority of children (Chaput et al., 2016; Okely et al., 2021; Timmons et al., 2012). Adequate levels of MC in the early years positively influence physical activity and other health indicators like cardiorespiratory fitness and adiposity (Timmons et al., 2012; Robinson et al., 2015), and children who spend more time in SB may have fewer opportunities to develop their MC (Dos Santos et al., 2021; Drenowatz & Greier, 2019). Therefore, reducing the time a child spends sedentary may assist the acquisition of adequate MC, which can in its turn influence physical activity and health later in life (Utesch et al., 2019; Timmons et al., 2012).

Some strengths of the current review include the application of rigorous methodological standards established for conducting a systematic review (PRISMA) (Page et al., 2021). Authors used a comprehensive search strategy developed with the help of a librarian with an expertise in systematic review and searched a comprehensive list of the most relevant databases. The quality of the included studies was assessed using the Joanna Briggs Institute assessment tools, which are both valid and reliable (Tufanaru et al., 2017). The review assessed the individual components of both times spent in habitual SB and screen time to provide a greater understanding on the impact different SB might have on different aspects of MC. The review does not come without limitations. Studies were limited to those published in English language only. Also, due to the heterogeneous nature of the exposure and outcome measures, meta-analysis was not possible. Finally, the majority of studies included small sample sizes (10 out of 13 eligible studies had fewer than 500 participants), which may have limited their statistical power.

This review has also highlighted several areas for future research. Most of the included studies used parent questionnaires for measurement of screen time validity, and the reliability of these has not been ascertained with 3-4-year-olds (Philips et al., 2021). There is a need for the development of proxy-reported or other instruments that can accurately capture screen time (Byrne et al., 2021). Establishing

a high-quality standard measure for time spent in habitual SB remains a challenge, and a uniform approach to data collection would help minimise some of the challenges associated with quantifying SB in young children, as well as providing a more comparable evidence base. In future studies, measuring tools such as inclinometers which capture postures more accurately than hip worn accelerometery and have been used and validated in this population may be adopted (Mwase-Vuma et al., 2022; Davies et al., 2012). Further studies with more valid and reliable measurement tools, and a stronger study design (such as prospective studies and intervention studies) may be required to confirm the associations between screen time and/or SB and MC in 3–4-year-olds to validate findings from this review. Further investigation of screen time and habitual sedentary behaviours over different time periods may also provide a better understanding on its association with motor competence in children between 3 and 4 years. The authors do recommend time spent on screens or habitual sedentary behaviour should be reported in time spent per day to enable comparison to the WHO guidelines and enable future studies to examine dose-response relationships. It will also be interesting for future studies to measure individual screen time types like TV watching or mobile devices to assess their specific/possibly differential impact on motor competence. Future studies may also investigate parental influence of children's screen time as parents play a facilitating role on children's screen time at home.

2.7 Conclusion

This systematic review synthesised findings from 16 studies with 7,424 participants from different parts of the world. Quality of evidence was moderate. In summary, this review showed a predominantly negative association of screen time and habitual SB with motor competence in 3- and 4-year-olds. Findings from this review extend and support the findings of previous reviews and highlight the importance of limiting both screen time and habitual SB in early years for promotion of optimal health outcome and development. Future studies may consider the use of measuring tools that are valid and reliable for use in target groups of population, as used for the outcome measure in this review. Although studies with a stronger study design may be required to confirm the association between sedentary behaviour and motor competence, findings from this study may be considered beneficial by health professionals and policy makers when designing strategies and interventions to help promote adherence to sedentary behaviour guidelines.

2.8 Key Messages

- Targeting high levels of screen time and sedentary behaviour may be used as a strategy to increase motor competence in young children.
- Studies examining the different types of sedentary behaviour on different components of motor competence are needed.
- High-quality studies with strong designs are needed to strengthen the evidence base.
- There is need for the development of self-reported or other instruments that can accurately capture screen time measurement and can do so across different screen-based devices.

2.9 Preface References

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Chapter 3: Associations between Sedentary Behaviour and Fine and Gross Motor Skills in 3-4-year-olds: A Secondary Data Analysis from SUNRISE International Study Pilot Studies

3.1 Preface

This preface to the chapter aims to present a comprehensive description of the methodology and to provide any additional information and justification for the methodology used in the secondary data analysis study that could not be included in the manuscript due to word restrictions from the journal. The study "Associations between sedentary behaviour and fine and gross motor skills in 3-4-year-olds: a secondary data analysis from SUNRISE international study pilot studies" has been published in the Child: Care, Health and Development journal. The study was conducted by Nana Kwofie (lead author) and supervised by Dr Xanne Janssen and Professor John J Reilly. Chief investigators for all the countries used in this analysis were included as co-authors of the study. All authors read and approved of the final manuscript prior to submission to the journal.

3.1.1 Introduction and Rationale

The systematic review in chapter 2 of this thesis highlighted evidence suggesting that sedentary behaviour may negatively impact the motor competence of children aged 3-4 years. The review reported a predominantly negative association of increased screen time and habitual sedentary behaviour with motor competence in 3-4-year-olds. However, the majority of studies included in the review had small sample sizes and were conducted in predominantly high-income countries. Furthermore, some studies of sedentary behaviour and motor competence included 'pre-schoolers' as children up to 6 years old, differing from the WHO 2019 Guideline target population of children 3-4 years.

To address these limitations, the second study in this thesis, a secondary data analysis, analysed data from the SUNRISE International study (details explained in section 3.1.2 below). Data obtained from the SUNRISE study includes participants from diverse populations across various geographic, cultural, and socioeconomic contexts, representing a wide range of Human Development Indices (HDIs), including many low- and middle-income countries (LMICs) (Okely et al., 2021). Using the SUNRISE

International standardised protocol, which is adequate and feasible for this age group, provides appropriate and comprehensive data that may be useful for examining the association between sedentary behaviours and motor competence in 3–4-year-olds.

3.1.2 Justification for Methodology Used

As mentioned earlier, this is a secondary data analysis study using data from the SUNRISE International study. Secondary data analysis involves examining data initially collected by others for a different primary purpose and offers a practical solution for researchers who face constraints such as limited time or resources (Johnston, 2017). Utilising secondary data from the SUNRISE International Study provided the authors with access to a pre-existing, readily available, comprehensive, high-quality dataset. In addition, it enabled the authors to analyse a large sample including participants across different demographic regions from both high and low-income countries. This approach was time- and cost-efficient, avoiding the need for primary data collection and related ethical concerns, allowing the authors to focus on data analysis.

3.1.3 Secondary Data Sourcing Process

For the secondary analysis, a formal data request was submitted to the SUNRISE International coordinating centre in Australia. The request specified the target age group (3–4 year olds) and the variables required for the present study, including parent-reported screen time and restraint measure, sedentary time as measured by the activPAL, and fine and gross motor skill outcomes assessed using the Ages and Stages Questionaire-3. The SUNRISE research protocol was also requested to ensure alignment with the original data collection procedures. Following approval, access to the dataset was provided via a secure link for a specified time period. The dataset had undergone initial cleaning by the SUNRISE international coordinating team; therefore, the present analysis involved variable selection, filtering for the eligible 3-4 year age group, and screening for completeness relevant to the study aims. The dataset was then imported into SPSS for iOS (version 29.0) for analysis. Descriptive analyses were first conducted to characterise the sample. Linear regression models were used to examine associations between continuous exposure and outcome variables, while logistic regression analyses were performed

where outcomes were categorical, allowing estimation of odds ratios to determine the likelihood of being on track for fine and gross motor skills.

3.1.4 The SUNRISE International Study

The SUNRISE International Study of movement behaviours in early years (https://sunrise-study.com) is an international study whose primary aim is to determine the proportion of 3- and 4-year-olds from participating countries who meet the WHO Global guidelines for physical activity, sedentary behaviour, and sleep (Okely et al., 2021; WHO, 2019). Other aims of this international study body include determining potential correlates of movement behaviours and associations between movement behaviours and health and developmental outcomes. The SUNRISE International study is designed to collect data from both urban and rural communities in participating countries (Okely et al., 2021).

3.1.5 Participants Recruitment and Data Collection

Recruitment of countries to participate in the SUNRISE study has occurred continuously, with the goal of achieving geographic representation across the World Bank income classifications (low, middle, high, and very high) (Okely et al., 2021). Participating countries aim to recruit approximately 1000 (500 each from urban and rural communities) healthy, gender-balanced 3-4 year olds for the main study. However, prior to conducting the main study, participating countries conducted pilot studies to evaluate the practicality and suitability of the study protocol, with a specific focus on the effectiveness of recruitment strategies and data collection methods (Okely et al., 2021). Overall, eight countries participated in phase 1 (March 2018 - July 2019), 12 in phase 2 (August 2019 - September 2020), and 21 countries are currently involved in phase 3 of the pilot study (Okely et al., 2021).

Participants included in this study were recruited as part of phases 1 and 2 of the SUNRISE international study, as these were the only phases that used the activPAL activity monitor to objectively measure sedentary behaviour. (Okely et al., 2021). Informed consent was provided by the children's parents/guardians. A target of 100 children aged 3 and 4 years per country was used for each SUNRISE pilot study, with an equal split between urban and rural areas (50 children from each group), and each

country applying its own national definitions to distinguish between urban and rural settings. Overall, data from 19 countries were used in the analysis of this present study (Australia (53), Bangladesh (52), Brazil (66), Canada (100), China (144), Hong Kong (89), Indonesia (86), Japan (78), Malaysia (130), Morocco (32), Papua New Guinea (90), Scotland (31), South Africa (77), South Korea (34), Sri Lanka (68), Sweden (94), USA (25), Vietnam (125), Zimbabwe (20)), with the numbers in parentheses representing the number of participants recruited from each site.

Data collection for the SUNRISE study was conducted by trained researchers. Videos were developed to demonstrate the assessment protocols, and practice assessments were conducted over Zoom or recorded and sent to the coordinating centre for feedback (publicly available on the SUNRISE YouTube channel https://www.youtube.com/channel/UCUgmfAGHO1q_W7HV73vDVSLw). Parents/guardians of all 3-4 year-old children attending participating childcare centres and schools were invited to participate in the study. Participating children needed to be in good health without any physical disability or developmental disorders that could prevent them from wearing the accelerometer or understanding instructions for completing motor skills assessments. Participants who declined to participate in the study's measures were excluded.

3.1.6 Objective Measure of Total Daily Sedentary Behaviour

Accelerometers are often the preferred choice for measuring children's free-living physical activity, as they are practical and widely used, which can be beneficial for comparative purposes (Trost, 2007). As highlighted in the published paper, this study used activPAL-measured data to estimate participants' total daily sedentary behaviour (termed Sedentary Behaviour in this study). The activPAL™ 4 (PAL Technologies Ltd., Glasgow, UK) is a small, discrete and lightweight activity monitor worn on the front right thigh and held in place with surgical tape (Chastin et al., 2018; De Decker et al., 2013). It can be made waterproof, making it suitable for water activities, allowing for an accurate estimate of habitual movement behaviour (Penpraze et al., 2006; Aadland et al., 2020). The activPAL is also valued for its

validity and reliability in sedentary behaviour measures in children 0-5 years, and for being lightweight and unobtrusive, making it suitable for use with young populations (Davies et al., 2012; Janssen et al., 2014; Gwyneth et al., 2011; Aminian et al., 2012).

One advantage of the activPAL device is its ability to detect posture with high precision and to discriminate between standing and sitting/lying, whereas other accelerometers are less accurate in measuring sedentary behaviours and may include standing time (Penpraze et al., 2006; Aadland et al., 2020). It captures not just the duration of sedentary periods but also transitions (e.g., from sitting to standing) and patterns of activity, making it appropriate to measure children's duration and frequency across a desired period of time (Dowd et al, 2012; Davies et al, 2012; Kozey-Keadle et al., 2011). Barboza et al. (2016), in a study comparing the ActiGraph and activPAL to assess sedentary behaviour among school children, reported that the ActiGraph GT3X model may overestimate sedentary time because it cannot differentiate between body postures, treating standing as stationary time (Barboza et al., 2016). In light of this, the authors preferred the activPAL-measured data for sedentary behaviour.

The activPAL was initialised to begin recording at 12:00 am on the morning of the first day of data collection. Raw data from the activPAL were processed using the activPAL proprietary algorithms through PALbatch software (v8.10.12; PAL Technologies Ltd., Glasgow, Scotland). For analysis, an event file was produced using the Standard PAL Analysis Algorithm (VANE), which categorises activity events into three primary states- sitting/lying, standing, and stepping—based on thigh positioning and dynamic acceleration data.

A visual inspection of the files was conducted to identify children with at least 1 day of complete 24-hour data. While using a single day activPAL measure may be a limitation, as sedentary behaviour can vary from day to day, this approach was a pragmatic decision balancing data availability and compliance challenges in 3-4 year olds. In this age group, compliance to the device wear can be challenging, with device removal being a possibility. Requiring 3 valid days would have reduced the sample size in this study by 807 participants which would have substantially reduced statistical power and introduced and introduced selection bias. Again, while a single day may not perfectly capture habitual sedentary

behaviour at the individual level, it can still provide reasonable group-level estimates for examining associations (Migueles et al., 2022; Rowlands et al., 2023). Although a 3–5 valid days would have provided more stable habitual estimates (Davies et al., 2012a; Hislop et al., 2014), the use of the activPAL which provides posture-based measurement, strengthens the validity of sedentary time estimation despite the use of a single valid day measurement (Lyden et al., 2020; Kozey-Keadle et al., 2021).

Waking hours for each wear day were determined using the built-in algorithm that detects sleep onset and offset times. Children with any periods of non-wear time were excluded from the analysis. Sedentary behaviour was calculated using the 'sitting time' output variable as recorded by the activPAL.

3.1.7 Subjective Measure of Screen Time and Restraint

As mentioned in the published paper, the SUNRISE international study team used a parent report questionnaire to collect data on participants' screen and restraint time. The questionnaire was developed based on recommendations from the surveillance subcommittee of the Guideline Development Group for the Australian 24-hour movement behaviour guidelines for the early years in 2017 (Okely et al., 2021). Although the questionnaire in its entirety has not been validated for use in children 3-4 years, the SUNRISE international parent questionnaire is recognised for its practicality and cultural relevance, making it suitable for use in both high-income countries (HICs) and low- and middle-income countries (LMICs) and has demonstrated face validity, such as distinguishing between-group differences based on levels of national economic development (Nystrom et al., 2020; Hossain et al., 2021).

To ensure clarity, all questionnaires were translated into the respective local languages and administered by trained enumerators in each country. Parents completed the questionnaires, reporting the total time their child spent using digital screens each day (in minutes per day) (Sallis et al., 2000). Additionally, parents were asked to report times when their child was restrained for more than one hour at a time (e.g., in a car seat or stroller) (Sallis et al., 2000). Children were categorised as meeting the screen time guideline if they spent ≤ 60 min per day using screen-based electronic devices, and children who did not spend more than one hour at a time restrained were classified as meeting the restrained guidelines,

in line with the WHO guidelines for under 5s (WHO, 2019). A complete copy of the parent/guardian questionnaire is presented in Appendix 1 of the thesis.

Although parent-reported questionnaires remain the most widely used method for assessing screen time in young children due to 1) their feasibility and low burden and 2) the lack of a validated and reliable objective measure for screen time, they may be subject to recall and social desirability biases, which can limit accuracy (Radesky et al., 2020; Madigan et al., 2022). Some emerging objective approaches that may offer alternatives and provide more precise estimates of screen time include screen use analytics built into mobile devices or external sensors or monitoring devices connected to televisions or other screens to track actual viewing time (Wu et al., 2021; Rosenkranz et al., 2023). However, these objective measures should be validated, with their reliability examined within children 3-4 year old. Incorporating such technologies in future studies may improve the validity of screen time measurement.

3.1.8 Gross and Fine Motor Skills Measure

Gross and fine motor skills were assessed using the Ages and Stages Questionnaire. This is a developmental screening tool designed to assess the developmental progress of children from 1 month to 5.5 years of age (ASQ-3, 2024). It provides a valid and reliable method for evaluating multiple developmental milestones across gross and fine motor domains through a structured series of age-appropriate questions and activities (ASQ-3, 2024). It is an effective measure of children's development that offers insights into their typical behaviour in their natural environment, and enables early identification of developmental concerns, which is crucial for timely interventions and supporting optimal development (Skonkoff et al., 2000). The ASQ consists of a series of tasks that focus on various developmental domains, such as communication, problem-solving, personal-social skills, and motor skills (Squires et al., 2009). For gross motor skills, children's ability to complete activities related to balance, coordination, and movement was assessed, while fine motor skills were assessed through smaller, more controlled movements of the hands and fingers.

The gross and fine motor sections of the ASQ-3 were used to assess the gross and fine motor skills of participants in the SUNRISE study. All staff involved in the study underwent two days of training

covering all steps of the data collection process, with a particular focus on administering assessments for this age group (Okeley et al., 2021). The training process involved watching online training videos, being observed by trainers while practising assessments on children, viewing protocol videos, and passing a test on the assessment protocol as part of the in-person training conducted by experts, to ensure that assessment practices were standardised across the participating countries. During visits to childcare centres or schools, participating children were asked to perform tasks related to gross and fine motor skills, with items scored by trained research staff. Gross motor tasks included catching a large ball, overhand throwing to a person 180 cm away, one-legged hopping, forward jumping 50 cm, and balancing on one foot for 5 seconds. Fine motor tasks included assembling a 5-7-piece puzzle, cutting paper in half along a straight line with scissors, drawing shapes, unbuttoning one or more buttons, drawing a person with at least three features, and colouring within the lines of a 2-inch circle.

For each item on the questionnaire, children's ability to complete the task is rated as either "yes" (when the child performed the skill consistently), "sometimes" (when the skill was performed on occasion but inconsistently) or "not yet" (when the child was unable to perform the skill at all). The answers are then scored, and their total scores are compared to age-appropriate developmental milestones (Bricker et al., 2011). Details of the ASQ-3 fine and gross motor tasks used in assessing participants in this study are shown in Appendix 2 of the thesis.

3.1.9 Data Analysis

Participants in the SUNRISE pilot study were recruited from childcare centres across participating countries, which introduces the potential for clustering effects, as children within the same centre may share similar environmental or contextual characteristics. To minimise the influence of clustering at the recruitment stage, the SUNRISE protocol limited the number of participants recruited from each centre to a maximum of 20 children (Okely et al., 2021). However, formal multilevel modelling techniques were not applied in the present secondary analysis. Given the exploratory nature of the pilot dataset and the distribution of participants across multiple centres and countries, the primary analyses were conducted using standard linear and logistic regression models. While this approach allowed examination of associations between sedentary behaviour and motor competence, it is acknowledged

that future studies using larger samples may benefit from the application of multilevel modelling techniques to account for potential centre-level clustering and contextual influences on children's sedentary behaviours and developmental outcomes.

3.1.10 Conclusion

The preface section of this chapter aimed to provide additional information on the rationale and justification for the methods used for the published secondary data analysis study, which will now be presented exactly as submitted to the Child: Care Health Development journal.

Manuscript 2: Associations between sedentary behaviour and fine and gross motor skills in 3–4-year-olds: a secondary data analysis from Sunrise International Study pilot studies

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Associations between Sedentary Behaviour and Fine and Gross Motor skills in 3-4 year olds: A secondary Data Analysis from SUNRISE International Study Pilot Studies

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Conflict of interest: Authors declare no conflict of interest.

Ethical approval: The SUNRISE study protocol received ethical approval from the University of Wollongong, Australia (2018/044) and in each country by the applicable ethics committees.

3.2 Abstract

BACKGROUND: The evidence on associations between sedentary behaviour (SB) and motor skills in 3-4-year-olds is unclear and mostly from high-income countries.

OBJECTIVE: To examine associations between 1) screen time (hours/day) and total daily SB (hours/day), and gross and fine motor skills; and 2) meeting the restraint, screen time, and overall SB (restraint and screen time) guidelines and fine and gross motor skills.

METHODS: Cross-sectional study of 1,394 3-4-year-olds from the pilot phase of the SUNRISE International study. Time spent in SB was measured using the *activ*PAL^{TM} accelerometer, while screen time and restraint were measured using a parent questionnaire. Fine and gross motor skills were measured using parent-reported Ages and Stages Questionnaire (ASQ-3). Associations between SB and motor skills were determined using linear and logistic regression, adjusting for sex and socioeconomic status.

RESULTS: Every additional 1 hour of screen time was associated with a 0.50-point reduction in gross motor skills scores (p=0.008). More screen time was associated with decreased odds of being on track for fine and gross motor skill development (p<0.001; p=0.017, respectively). Meeting the screen time (p=0.009) and overall SB guidelines (p=0.006) were favourably associated with fine motor skills scores. Meeting the screen time, restraint, and overall SB guidelines were favourably associated with gross motor skills scores (p=0.007, p<0.001, p<0.001, respectively), and higher odds of being on track for fine (p=0.033; p=0.015; p<0.001 respectively) and gross motor skills (p=0.006; p<0.001; p<0.001 respectively) development.

CONCLUSION: The present study adds to the evidence on the importance of sedentary behaviour for the motor development of 3-4-year-olds. It is important that policymakers and health educators develop strategies that will encourage and promote adherence to sedentary behaviour guidelines among 3- and 4-year-olds.

KEYWORDS: Pre-schoolers, screen time, restrained sitting, motor competence, motor skills.

3.3 Introduction

In 2019, the World Health Organization (WHO) developed the first global guidelines for 24-hour movement behaviours for the under-5s, which included recommendations for sedentary behaviour (SB) (WHO, 2019). The WHO recommends that children aged 3-4 years do not accumulate more than one hour of screen time per day and are not restrained sedentary for more than one hour at a time (WHO, 2019). Several studies have examined the prevalence of meeting the guidelines, with a wide range of estimates (Kracht et al., 2020; McArthur et al., 2022; Tanaka et al., 2020; Hinkley et al., 2020; Nyström et al., 2020).

Children's gross motor skills, such as locomotor, object manipulation and stability skills, are instrumental for physical activities and are associated with healthy weight and cardiorespiratory fitness (Henrique et al., 2016; Lima et al., 2017; Cattuzzo et al., 2016). Gross motor skills are also considered the building blocks of movement (Stodden et al., 2008 or Clark & Metcalfe, 2002), and children with higher levels of gross motor skills have been shown to spend less time sitting and more time in moderate- to vigorous-intensity physical activities (Webster, Martin & Staiano, 2019). Fine motor skills, such as grasping, object manipulation, or drawing, facilitate participation in learning in preschool and early school years (Marr, Cermak, Cohn, & Henderson, 2003) and are linked positively to cognitive development (Roebers et al., 2014) and academic skills (Cameron et al., 2012).

Two systematic reviews (Dos Santos et al., 2021; Kwofie et al., 2023) have examined relationships between SB and motor skills. In addition, a systematic review by Li et al. (2020) and several more recent studies (e.g. Fadhli et al., 2022; Rogovic et al., 2022; Kim et al., 2022; Byambaa et al., 2024) have examined the relationship between screen time and motor development in pre-schoolers. The results of these systematic reviews and recent studies show inconclusive evidence on the relationship between SB and/or screen time and motor development in young children. In addition, most of these studies were conducted in high-income countries, and some studies included 'pre-school' participants up to 6 years old (Dos Santos et al., 2020; Li et al., 2020; Rogović et al., 2022), while the WHO 2019 Guidelines were developed specifically for children aged up to 4.9 years. Development in children

differs for each milestone, and in older children, SB may not have such a significant impact on motor development as in younger children. The 3-4-year age group is an important time when specific movement patterns and skills develop, providing the basis for acquisition of future complex skills (Malina, 1991). To better understand how SB relates to motor skill development, a focus on 3–4-year-olds will be helpful, as they are distinct from older and younger children. Further investigation with geographically and culturally diverse groups will help understand associations between components of SB (screen time, restraint, total daily accelerometer-measured SB) and motor skills in 3–4-year-olds.

The aim of the present study was to test for associations between SB and fine and gross motor skills in a diverse international sample of 3–4-year-olds. Specifically, to examine associations between 1) screen time (hours/day) and total daily accelerometery measured SB (hours/day), and gross and fine motor skills; and 2) meeting the restraint, screen time, and overall SB (restraint and screen time combined) guidelines and fine and gross motor skills.

3.4 Methodology

3.4.1 Sampling and Recruitment

Data from all eligible High-Income Countries (HICs) and Low- and Middle-Income Countries (LMICs) involved in the SUNRISE pilot study were pooled for use in this present study (n=19 countries; see supplementary file 1). Countries were eligible and included if they had collected data on the exposure and outcome measures for the present study.

Participants were recruited using a convenience cluster sampling approach either through Early Childhood Education and Care (ECEC) services or from the community (where ECEC services were limited). In countries where children were exclusively recruited from both public and private ECEC centres, a maximum of 20 children per centre were recruited to reduce the impact of clustering of data (i.e., influence of the centre) within the sample. Participating countries were encouraged to recruit a sample that was stratified in terms of sex, socioeconomic backgrounds of parents, and urban/rural residence. All data collectors underwent extensive training to assist with quality assurance and data standardisation (Okely et al., 2021).

Ethical approval was received from the University of Wollongong Human Research Ethics Committee (2018/044) and from the local ethics committee(s) in each participating country prior to the study commencing, and parents of participants provided written consent before participating.

3.4.2 Participants

Children eligible to participate were boys and girls between the ages of 3.0 and 4.9 years who were able to participate in ambulatory behaviours and could wear an accelerometer (Okely et al., 2021). Children were excluded if they had a physical disability that would preclude a child to engage in physical activity that may be recorded by the accelerometer placed on the thigh. Also, children who did not assent to participation in the study measures were withdrawn from the study.

3.4.3 Measures

An overview of all outcome and exposure measures is shown in Table 1a and 1b and described in more detail below.

1) Sedentary Behaviour

Total daily accelerometer measured SB - Total daily SB was measured using the *activ*PAL™ 4 (PAL Technology Ltd., Glasgow, Scotland), attached to the anterior mid-thigh. The use of the *activ*PAL™ has acceptable validity, practical utility, and reliability for the measurement of posture (time spent sitting and lying down) (Davies et al., 2012a; Davies et al., 2012b; De Decker et al., 2013). The activPAL monitors were made waterproof with a nitrile sleeve and wrapped in a Tegaderm transparent dressing. During a site visit, trained research personnel applied an additional dressing to attach the monitor to the child's right anterior thigh, positioned halfway between the hip and knee along the midline. Each child was asked to wear the *activ*PAL™ continuously for at least 72 hours and not take it off for any reason, including water activities (like bathing, swimming) and sleeping. Total daily SB was calculated using the 'sitting time' as recorded by the *activ*PAL, averaged over the valid days (i.e., 24 hours of wear) (Kariippanon et al., 2022). Only participants with at least one 24-hour period of wear were included in the final analysis.

2) *Screen Time*

Daily screen time was measured via the SUNRISE parent questionnaire (Okely et al, 2021). Parents or caregivers were asked to report on how much time their child spent using an electronic screen device such as a smartphone, tablet, video game, or watching television or movies, or videos on the internet, while they were sitting or lying down, recorded in minutes/day during the last seven days (Okely et al., 2021).

3) *Restraint*

Parents were asked whether their child was restrained for more than one hour at a time (e.g., in a stroller, car seat, or on a scooter/moped) using a parent questionnaire developed for SUNRISE (Okely et al., 2021).

4) *Compliance with the SB Guidelines*

Children were categorised as meeting the screen time, restraint, and overall guideline as outlined in Table 1b.

While the validity and reliability of the screen time and restraint questions are unknown, the use of the SUNRISE parent questionnaire is practical and culturally appropriate (can be used in both HICs and LMICs), is in line with the WHO 2019 Movement Guidelines for the corresponding age group, and has been shown to have face validity, e.g., in identifying between-group differences (Abdeta et al., 2024; Hossain et al., 2021).

5) *Parent Demographic Characteristics*

Child and parent/caregiver's age, sex, education level, and cultural background were recorded. Socio-economic status (SES) was defined using parent education level.

6) Gross and Fine Motor Skills

Trained researchers measured the fine and gross motor skill performance of participants using the Ages and Stages Questionnaire-3 (48 months, ASQ-3), which is a developmental screening assessment (ASQ-3, 2024). The validity and reliability of this questionnaire have been established in children under 5 years (e.g. Fuengfoo et al., 2020; Shariatpanahi et al., 2024).

Participants were asked to perform six tasks for each fine and gross motor skill. Scoring for the ASQ-3 involves assigning 10 points for "yes", 5 points for "sometimes", and 0 points for "not yet" for each task, and, from that, a total score for each subscale (gross and fine motor skills) is computed. The total scores for each subscale were the sum of points for all activities performed on fine or gross motor skills, with a maximum of 60 points. Gross and fine motor skills were categorized as 'on track' if total scores were greater than 42.74 and 30.58 respectively; 'at risk' if the total score was between 42.74 and 32.78 for gross motor skills and between 30.58 and 15.81 for fine motor skills; and 'delayed' if the total score

was below 32.78 and 15.81 respectively, in line with the standard ASQ-3 scoring procedure (ASQ-3, 2024).

Table 1a. Continuous Variables and Measurement Tools with their Validity and Reliability.

Exposure Variable	Measurement	Validity and Reliability
Screen Time (mins/day)	Subjective measure using the SUNRISE parent questionnaire.	Not validated, but practical and culturally appropriate with some face validity (Kariippanon et al., 2022; Hossain et al., 2021)
Restraint (mins /day)	Subjective measure using the SUNRISE parent questionnaire.	Not validated, but practical and culturally appropriate with some face validity (Kariippanon et al., 2022; Hossain et al., 2021)
Total Daily SB (hours/day)	Objective measure using *activ*PAL™ 4.	Validated and reliable in children under 5 years old (Davies et al., 2012a; Davies et al., 2012b; Janssen et al, 2014)
Outcome Variable	**Measurement**	**Validity and Reliability**
Fine Motor Skills Scores (continuous data)	Objective measure using Ages and stages questionnaire 3.	Validated in children under 5 years (e.g. Fuengfoo et al. 2020; Shariatpanahi et al., 2024)
Gross Motor Skills Scores (continuous data)	Objective measure using Ages and stages questionnaire 3.	Validated in children under 5 years (e.g. Fuengfoo et al. 2020; Shariatpanahi et al., 2024)

Table 1b. Categorical Variable Table and Measured Outcome.

Exposure Variable	Measured Exposure	Categorised Outcome
Screen Time Guideline	Meeting ≤ 1 h/day of screen time	• 0- If they did not meet the screen time guideline. • 1- if they met the screen time guideline.
Restraint Guideline	Meeting ≤1 h at a time spent restrained	• 0- If they did not meet the restraint guideline. • 1- if they met the restraint guideline
Overall SB Guideline	Meeting ≤1 h/day of screen time and ≤1 h at a time spent restrained	• 0- If they did not meet both guidelines. • 1- if they met both the guidelines
Outcome Variable	**Measured Outcome**	**Categorised Outcome**
Fine Motor Skills	Total score of the sum of all task score (0-not yet; 5-sometimes; 10-yes)	• On track (if total score is above 30.58). • At risk (if total score is between 15.81 and 30.58). • Delayed (if total score is less than 15.81)
Gross Motor Skill	Total score of the sum of all task score (0-not yet; 5-sometimes; 10-yes)	• On track (if total score is above 42.74). • At risk (if total score is between 32.78 and 42.74). • Delayed (if total score is less than 32.78)

3.4.4 Data Reduction and Analysis

All statistical analyses were performed using SPSS Statistics for iOS version 29.0 (IBM Corp, Armonk, NY). Only participants with valid data on at least one of the predictors (screen time, restraint, or total daily SB) and outcome (fine or gross motor skills) measures were included for the analysis. Descriptive statistics (mean, standard deviation) were computed for all study variables, including total daily SB (hours/day) and screen time (hours/day). The proportion of children meeting the screen time and restraint guidelines, individually and in combination, was reported. Independent t-tests and Pearson's chi-square tests were used to test the difference between sexes.

Univariable regression analysis was used to examine the association between meeting and not meeting the screen time guidelines, restraint guidelines, overall SB guidelines, screen time (hours/day), and the total daily SB (hours/day), and fine and gross motor skills. A multivariable regression analysis was performed for all variables with a significance of $p<0.1$ in the univariable analysis.

The association between meeting and not meeting the screen time guidelines, the restraint guidelines, the overall SB guidelines, the screen time (hours/day) and total daily SB (hours/day) and being on track for fine and gross motor development vs. delayed/at risk was examined using univariable logistic regression. Multivariable logistic regression, including sex and SES, was conducted for those variables with a significance of $p<0.1$ in the univariable analysis. Statistical significance was set at $p<0.05$.

3.5 Results

3.5.1 Characteristics of Study Participants

A total of 1490 children were recruited, 1394 completed the study protocol and met the data requirements of the present analyses, with 768 from urban and 626 from rural areas. The mean age of participants was 4.4 years (SD=0.4) with 708 boys and 686 girls. Table 2 shows the descriptive characteristics of participants. Forty two percent (n=567) of children met the overall SB guideline, while 50.1% (n=671) and 82.2% (n=1118) of children met the screen time and restraint guidelines, respectively. No statistically significant differences were found between boys and girls in meeting the SB guidelines. For fine motor skills, girls had higher scores than boys (Mean ± SD [47.9 ± 13.1] vs. [42.9 ± 16.0]) points respectively, $p<0.001$). No significant differences in gross motor skill scores were observed between boys and girls. The percentages of all children who were developmentally on track for fine and gross motor skills were 66.2% and 74.4%, respectively. A higher proportion of girls than boys were developmentally on track (vs at risk) for fine and gross motor skills.

Table 2. Descriptive Characteristics of the Participating Children, the Overall Scores for Gross and Fine Motor Skill (mean ± standard deviation) and Proportion of Children Meeting the SB Guidelines, Stratified by Sex.

	Total (n=1,394)	**Boys (n=708)**	**Girls (n=686)**	**P-value**
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	
Age	4.4 (0.4)	4.4 (0.4)	4.4 (0.4)	0.473
Total daily SB (hours/day)[a]	7.4 (1.7)	7.5 (1.7)	7.4 (1.6)	0.207
Screen time (hours/day)[b]	1.7 (1.6)	1.7 (1.6)	1.6 (1.5)	0.579
Fine motor skills[c]	**45.4 (15.0)**	**42.9 (16.0)**	**47.9 (13.1)**	**< 0.001**
On track n (%)	919 (66.2)	419 (59.5)	500 (73.1)	
Gross motor skills[d]	**50.1 (11.4)**	**50.2 (12.3)**	**51.9 (10.3)**	**0.232**
On track n (%)	1037 (74.4)	508 (71.8)	529 (77.1)	
Meeting screen time guideline[e] n (%)	671 (50.1)	341 (50.8)	330 (49.2)	0.912
Meeting restraint guideline[f] n (%)	1118 (82.2)	569 (50.9)	549 (49.1)	0.801
Meeting the overall SB guideline[g] n (%)	567 (42.4)	288 (50.8)	279 (49.2)	0.874

Differences between sex tested using independent t-test, [a]n= 881; [b]n= 1340; [c] n=1388; [d]n=1394; [e]n=1340; [f]n= 1360; [g]n= 1338. **Bold** values indicate statistically significant at $p < 0.05$.

3.5.2 Associations between SB and Gross and Fine Motor Skills Scores

Table 3 displays the results for the univariable and multivariable regression analysis. In the univariable analysis, meeting the restraint guideline (p=0.016) or overall SB guideline (*p*=0.007) was favourably associated with fine motor skills. Accumulating 1 hour more daily screen time was associated with a 0.55-point reduction in fine motor skills scores (*p*=0.027). There was a favourable association between meeting the screen time (p=0.005), restraint (p<0.001) and overall SB guidelines (p<0.001) with gross motor skills scores. Accumulating 1 hour more screen time daily was associated with a 0.53-point reduction in gross motor skill scores (*p*=0.005). No significant association was observed with total daily SB and fine or gross motor skill scores.

For the multivariable regression analysis, there were favourable associations between meeting the screen time guideline (*p*=0.009) and the overall SB guideline (p=0.006) with fine motor skills scores. Favourable associations were found between meeting the screen time guideline (p=0.007), the restraint guideline (p< 0.001), and the overall SB guideline (*p*< 0.001) and gross motor skills. Accumulating 1 hour more screen time daily was associated with a 0.50-point reduction in gross motor skills scores (*p*=0.008).

Table 3. Univariable/Multivariable Linear Regression Analysis (Corrected for Sex and Parent Education) Showing the Association between Meeting the Different Components of SB and Fine and Gross Motor Skills Scores.

	Univariable Analysis			**Multivariable Analysis**		
	Fine motor skill			Fine motor skill		
	Unstandardised Beta	95% CI	p-value	Unstandardised Beta	95% CI	p-value
Meeting Screen Time Guideline[a]	1.358	(-0.242, 2.958)	0.096	2.715	(0.667, 4.763)	**0.009**
Meeting Restraint Guideline[b]	2.547	(0.479, 4.614)	**0.016**	1.36	(-0.222, 2.942	0.092
Meeting Overall SB Guideline[c]	2.236	(0.618, 3.854)	**0.007**	2.233	(0.631, 3.835)	**0.006**
Total Daily SB (hours/day)[d]	0.503	(-0.100, 1.105)	0.102			
Screen Time (hours/day)[e]	-0.55	(-1.038, -0.062)	**0.027**	-0.031	(-0.110, 0.048)	0.439
	Gross motor skill			Gross motor skill		
	Unstandardised Beta	95% CI	p-value	Unstandardised Beta	95% CI	p-value
Meeting screen time guideline	1.772	(0.545, 2.998)	**0.005**	1.689	(0.462, 2.916)	**0.007**
Meeting restraint guideline	3.052	(1.469, 4.634)	**< 0.001**	3.094	(1.509, 4.679)	**< 0.001**
Meeting overall SB guideline	2.489	(1.250, 3.727)	**< 0.001**	2.405	(1.164, 3.646)	**< 0.001**
Total daily SB (hours/day)	0.011	(-0.441, 0.463)	0.962			
Screen time (hours/day)	-0.531	(-0.904, -0.158)	**0.005**	-0.504	(-0.877, -0.132)	**0.008**

Bold values indicate statistically significant at $p < 0.05$; [a]n= 1340; [b]n= 1360; [c] n=1338; [d]n=881; [e]n=1340

3.5.3 Associations between SB and the Odds of Being on Track (vs at risk/delayed) for Fine and Gross Motor Skills Development

The univariable logistic regression analysis showed a favourable relationship between meeting the screen time guideline (p=0.035), the restraint guideline (p=0.023), and the overall SB guideline (p<0.001) and being on track for fine motor skill development. Favourable associations were also found between meeting the screen time guideline (p=0.004), the restraint guideline (p<0.001), and the overall SB guideline (p<0.001) and being on track with gross motor skills development. Children who accumulated 1 hour more screen time per day were less likely to be on track for fine motor skill (p<0.001) and gross motor skill (p<0.001) development. No significant association was observed with the total daily SB and being on track for either fine or gross motor skill development.

For the multivariable logistic regression analysis, favourable associations were found between meeting the screen time guideline (p=0.033), the restraint guideline (p=0.015), and the overall SB guideline (p<0.001) and being on track for fine motor skill development. There were favourable associations with meeting the screen time guideline (p=0.006), the restraint guideline (p<0.001), and the overall SB guideline (p<0.001), and with being on track for gross motor skill development. Children who accumulated 1 hour more screen time were 0.86-times less likely to be on track for fine motor skill development (p<0.001) and 0.91-times less likely to be on track for gross motor skill development (p=0.017).

Table 4. Univariable/Multivariable Logistic Regression (Corrected for Sex and Parent Education) Showing the Association Between Meeting the Different Components of SB and Odds Ratio for Being on Track for Motor Skills Development (vs. Delayed/at risk).

	Univariable analysis				Multivariate analysis			
	On Track for Fine Motor Skill (vs. Delayed/At risk)		On Track for Gross Motor Skill (vs. Delayed/At risk)		On Track for Fine Motor Skill (vs. Delayed/At risk)		On Track for Gross Motor Skill (vs. Delayed/At risk)	
	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Meeting Screen Time Guideline	1.278 (1.017, 1.605)	**0.035**	1.439 (1.125, 1.841)	**0.004**	1.286 (1.021, 1.620)	**0.033**	1.419 (1.108, 1.818)	**0.006**
Meeting Restraint Guideline	1.396 (1.048, 1.860)	**0.023**	1.680 (1.246, 2.266)	**<0.001**	1.435 (1.073, 1.920)	**0.015**	1.697 (1.256, 2.292)	**<0.001**
Meeting Overall SB Guideline	1.489 (1.178, 1.882)	**<0.001**	1.653 (1.280, 2.135)	**<0.001**	1.500 (1.183, 1.903)	**<0.001**	1.631 (1.261, 2.109)	**<0.001**
Total Daily SB (hours/day)	1.034 (0.948, 1.127)	0.453	1.007 (0.918, 1.105)	0.882				
Screen Time (hours/day)	0.855 (0.790, 0.924)	**<0.001**	0.911 (0.847, 0.980)	**<0.001**	0.855 (0.789, 0.926)	**<0.001**	0.914 (0.849, 0.984)	**0.017**

Bold values indicate statistically significant at $p < 0.05$; [a]n= 1340; [b]n= 1360; [c] n=1338; [d]n=881; [e]n=13

3.6 Discussion

3.6.1 Findings and Study Implications

Findings from the present study show that accumulating more screen time (hours/day) was associated with poorer fine and gross motor skill scores and lowered the odds of being on track for fine and gross motor development. Meeting the screen time guideline and the restraint guideline, individually and in combination, were favourably associated with fine and gross motor skill scores and increased the odds of being on track with fine and gross motor skill development. The present study also showed low adherence to the overall SB guideline (42%), which may indicate that many children between 3 and 4 years are being exposed to excessive screen time and high sedentary time (more than the recommended time per day), and so are more likely to suffer from poorer fine and gross motor development. Findings from the present study, however, did not show a significant association between total SB and fine- and gross-motor skills scores.

Similar to findings reported in the present study, a systematic review by Li et al. (2020) and Kwofie et al. (2024) reported negative associations between screen time and motor competence. In addition, results reported in a systematic review by Feng et al. (2021) are consistent with those reported in this study, highlighting a positive association between meeting the screen time guideline and motor development in those aged 4-5 years (Feng et al., 2021). The present evidence on total SB is less consistent. The review by Dos Santos et al. (2021) reported inconclusive evidence on total SB: five included studies reported a negative association, five reported no association (similar to what was reported in the current study), and one reported an uncertain association. In addition, Kwofie et al. (2024) reported a mix of positive and negative associations between total SB and motor competence.

Findings from this present study add to the existing evidence that limiting certain types of SB (e.g. screen time) is beneficial for children's motor skill development. According to the conceptual model proposed by Stodden et al. (2008), adequate motor competence may promote physical activity and lead to long-term positive health trajectories. Children with increased screen time may have fewer opportunities to develop gross motor skills, which may increase their adoption of screen time and other

sedentary activities or may decrease their engagement in physical activity (Andrade et al., 2014; Hardy et al., 2018; Stodden et al., 2008).

Although findings from the current study align with previous studies, some differences should be highlighted. Findings from these previous studies did not address the research question addressed in this present study, which examined different components of SB in 3–4-year-olds with a diverse international sample. For example, the reviews by Li et al. (2020) and Dos Santos et al. (2021) included children older than 4.99 years of age and did not include any subgroup analysis of SB type or age (Li et al., 2020). In addition, Feng et al. (2021) reviewed adherence to the screen time guideline as the only exposure and only found two studies with pre-schoolers (aged 3-4.99 years), which may have limited comparability with the present study. These previous reviews also included studies from predominantly HICs, in contrast to the present study.

3.6.2 Strengths and Limitations

The SUNRISE Study has several strengths, including the use of device-based measures of the total daily SB, and the fine and gross motor skills measures with the ASQ-3, all of which have been validated within the 3 -4-year-old age group and have shown feasibility in global samples. Other strengths are a global and diverse sample of children across different countries, a focus on 3–4-year-olds, and different types of SB. The cross-sectional study design used in this study precludes causal inference; hence, further studies (e.g., longitudinal or interventional studies) are required to confirm the direction of association. Screen time was assessed using a parent questionnaire, for which validity and reliability have not yet been established; however, associations with outcomes such as gross and fine motor skills in the present study suggest that the questionnaire was measuring something meaningful. The *activ*PAL^{TM} data had a minimum of one day of valid day wear, which may not provide an accurate measure of usual SB. The accelerometer-measured SB may also be limited, as it cannot distinguish between different types of SB.

3.6.3 Conclusions

This current study suggests that screen time and restraint are associated with fine and gross motor skill development at age 3-4 years in many countries across a wide range of economic development. It is important that policymakers, health educators and other stakeholders promote and encourage adherence to the SB guidelines.

3.6.4 Acknowledgements

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3.6.5 Key Messages

- The WHO recommends that children aged 3-4 years do not accumulate more than one hour of screen time per day and are not restrained sedentary for more than one hour at a time.
- Studies suggest that children aged 3-4 years may be exceeding the WHO sedentary behaviour guideline.
- Findings from this study suggest that children 3-4 years exceeding the guideline recommendation are more likely to suffer from poorer fine and gross motor development
- Strategies and programs from policy makers, health educators and other stakeholders may be beneficial to promote and encourage adherence to the SB guidelines.

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Chapter 4: Sedentary Behaviour in 3-4-year-olds in Scotland and Parental Perceptions of Barriers to and Facilitators of Sedentary Behaviour Guidelines: A Mixed Method Study

4.1 Preface

This preface to the chapter is to present a detailed description of the rationale and justification for the methodology used, and to provide additional information which could not be included in the manuscript prepared for publication. The study "Sedentary behaviour in 3-4-year-olds in Scotland and parental perceptions of barriers to and facilitators of sedentary behaviour guidelines" is a mixed methods (quantitative and qualitative) study. The lead author was Nana Kwofie, and the co-authors were Dr Xanne Janssen, Professor John J Reilly, and Dr Andrew Dalziel.

4.1.5 Introduction and Rationale

Findings from the two studies (systematic review and secondary data analysis) presented in chapters 2 and 3 showed possible evidence of high levels of screen time among children aged 3-4 years and the possible negative impact it may have on their motor competence. Screen time in early years, as highlighted in the introduction chapter, is detrimental to children's overall health and development. With parents playing an important role in children's development and having an influence on their movement behaviours, including screen time, it is important to explore their perception of the influences of screen time in 3-4-year-olds. Gaining this insight could provide a valuable foundation for designing effective preventive interventions to reduce screen time among young children. The aim of this study is therefore to 1) examine parents' perception on barriers and facilitators to meeting the screen time guideline and 2) examine the difference in perception between those who meet and do not meet the guideline.

While the SUNRISE study provides valuable quantitative data from multiple countries to examine global insights into screen time among 3-4-year-olds, the decision to conduct the qualitative component

of this thesis in Scotland is grounded in contextual relevance. As a student researcher in Scotland, this was a practical and logistically feasible study, as it allowed for easier participant recruitment, greater control over data-collection quality (e.g., online group discussions in the same time zone), and reduced costs and coordination challenges compared to international qualitative fieldwork.

4.1.2 Justification for the Methodology used

This study used a quantitative and qualitative mixed method approach. Authors of this study adopted a mixed methods approach to gain a more comprehensive understanding of the influence of screen time on children aged 3-4 years. The quantitative part of the study supported the qualitative part, enabling us to discover differences between those who met and those who did not meet the guidelines. The integration of these methods allows for a more robust understanding of both "what" is happening (quantitative) and "why" it is happening (qualitative) (Creswell & Plano Clark, 2017).

4.1.3 Quantitative Study

As highlighted in the following manuscript, participants aged 3-4 years in Scotland were recruited for the study. Recruitment was conducted in two parts, before and after the COVID-19 period. Ethical approval was obtained from the University of Strathclyde ethics committee prior to the commencement of the study. Details of the participants, data recruitment and analysis process are highlighted in the methods (section 4.3) of the manuscript. A complete copy of the parent questionnaire used, which was developed from the SUNRISE international parent questionnaire, is presented in Appendix. N. Kwofie led the quantitative data collection, processing, and analysis under the supervision of Dr X Janssen and Prof J.J. Reilly.

4.1.4 Qualitative Study

Participants taking part in the quantitative phase were asked to take part in the qualitative phase. The Asynchronous Remote Communities (ARC) method (MacLeod et al., 2017) was used to collect qualitative data for this study. This is a participatory and flexible research approach designed to connect participants from geographically dispersed or remote areas. With the ARC method, participants interact

with researchers at different times rather than in real time, using tools like email, online discussion boards, or collaborative platforms, thereby reducing the need for travel or physical meetings (ARC, MacLeod et al., 2017). Authors of this study opted for this approach due to some of the benefits, including:

- *Accessibility*: This approach minimises barriers relating to geography, mobility, or time constraints that may come with data collection.
- *Inclusivity***:** It ensures that diverse voices, including those from marginalised or underserved communities, are heard and included.
- *Cost-Effectiveness*: It eliminates the costs involved in travelling or securing physical meeting spaces.
- *Flexibility*: This approach adapts to participants' schedules and availability, enhancing greater engagement.

Participants for the qualitative part of the study were recruited to a closed Facebook group. The use of a closed group ensured that only invited participants from the quantitative part of the study participated in the discussion, promoting a controlled, purposeful environment for in-depth discussion. (ARC, MacLeod et al., 2017). Over six weeks, two activities were posted each week, with parents/guardians invited to comment and share their views. These activities were designed to explore the barriers and facilitators they encounter when trying to build healthier daily routines for their children.

As stated in the study, the Braun and Clark reflexive approach was used to analyse the qualitative data. This is a widely recognised method for analysing qualitative data, providing a systematic yet flexible approach to identifying, analysing, and interpreting patterns (themes) within qualitative datasets (Braun & Clarke, 2014). This involves a six-phase approach for thematic analysis. In the first phase, which involved familiarisation with the data, NK read through the transcribed data thoroughly to gain a clear overview and observed and took notes on key information. In the second phase, initial codes were generated. This involved NK systematically reviewing the data and providing codes for data segments. In the third phase, NK grouped the codes into potential themes, which XJ reviewed in the fourth phase

to ensure relevance and coherence with the study's aims. The themes were then clearly defined by NK with names chosen to reflect their significance. In the sixth and final phase, a report of the generated themes was presented in a structured way for use in the study write-up.

Although the Braun and Clarke approach for reflexive thematic analysis offered several benefits that made it a preferred choice for authors, it also posed some difficulties, requiring careful, repeated engagement with the data and challenging the process of identifying and refining themes, which required analytical rigour. Further information on the analytical process is detailed in the main study.

Recruitment of participants for this study was done by both N Kwofie and Dr A Dalziel, while Dr A Dalziel led data collection for the qualitative study. N Kwofie led data collection for the quantitative study and the statistical analyses of both quantitative and qualitative studies, under the supervision of Dr Janssen and Prof J.J. Reilly.

The study design was intentionally structured to prioritise depth of engagement within the ARC method rather than extending the sample size. The six-week engagement period, with multiple structured prompts each week, generated a rich dataset capturing repeated reflections and interactions from participants. Furthermore, analysis indicated that the data generated were sufficiently rich and that key themes were recurring across participants, suggesting that meaningful thematic saturation had been reached. Therefore, there was no intent of extending data collection.

4.1.5 Conclusion

The preface section of this chapter aimed to provide additional information on the rationale and justification for the methods used for the mixed method study, which will now be presented below.

Study 3: Sedentary behaviour in 3-4-year-olds in Scotland and parental perceptions of barriers to and facilitators of sedentary behaviour guidelines: A mixed method study.

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Word count: 8830

Sedentary Behaviour in 3-4-year-olds in Scotland and Parental Perceptions of Barriers to and Facilitators of Sedentary Behaviour Guidelines: A Mixed Method Study

4.2 Introduction

Sedentary behaviour (SB), defined as activities of low energy expenditure (≤ 1.5 metabolic equivalents) while sitting, lying or reclining (Tremblay et al., 2017), in excess has been shown to be detrimentally associated with healthy growth and development in the early years (Poitras et al., 2017). High levels of sedentary behaviour in the early years may have negative consequences on health, given its potential to reduce time spent on physical activity or sleep, which are beneficial for young children's growth and development (Xie et al., 2020; Christakis, 2014). Reviews targeting young children indicate that the adverse effects of excessive screen time may include greater adiposity, poorer psychological health, and lower cognitive development (LeBlanc et al., 2012; Poitras et al., 2017). With studies showing that children aged 5 years and younger spent, on average, about 25% of their waking hours using screens (McArthur et al., 2022), children's health and development may be at risk due to excessive time spent in sedentary behaviours.

One of the predominant ways children accumulate sedentary behaviour is through screen time. In recent times, electronic media such as smartphones, television and computers have become a central and important aspect of communication and children in the early years are being exposed to these digital media earlier in life and for longer hours than in the past (Xie et al., 2020; Adank et al., 2018). Research examining the association between screen time and children's performance on a developmental screening test indicates that excessive screen time between the ages of 2 and 5 years is associated with developmental delays and later academic and social difficulties (Madigan et al., 2019). Again, a study by Hutton et al. (2020) has linked unhealthy use of screen time in 3- to 5-year-olds to reduced white matter integrity in brain areas that support language and the control of attention (Hutton et al., 2020).

Excessive screen time also results in brain structural changes in the early years related to cognitive control and emotional regulation (Lissak, 2015).

In 2017, Canada released the evidence-informed 24-hour movement guidelines for the early years, which were adopted by Australia, South Africa, New Zealand and the Asia Pacific region (Tremblay et al., 2017). The accumulated evidence on potential harms of screen time led to evidence-based guidance on screen time in 3-4 year olds by the World Health Organization (WHO). Building on the Canadian evidence base, the WHO also developed recommendations for children aged 3-4 years (WHO, 2019). The WHO recommendations state that children should not engage in more than an hour a day of screen time, and not be restrained for more than an hour at a time (WHO, 2019), however research shows that children between 3 and 4 years are typically experiencing much higher levels of screen time (Galland et al., 2012; Ofcom 2015, 2016; Okely et al., 2021; Chong et al., 2024). Several studies examining adherence to the WHO guidelines have reported low adherence to the screen time guideline. For example, studies have reported between 8%-51% of children between 3 and 5 years meeting the screen time guideline in Canada, South Africa, the USA and Brazil (Lucena Martins et al., 2020; Carson et al., 2019; Draper et al., 2020; Feng et al., 2021; Kracht et al., 2021). A recent study by Chong et al. (2024), which pooled analysis of data from 14 cross-sectional studies through systematic reviews and personal networks, shows an estimate of 42% of 3–4-year-olds meeting the screen time guideline globally, while 50% of the children met the screen time guideline for the WHO European region (Chong et al., 2024). The use of parent-reported questionnaires in measuring screen time in this review by Chong et al. (2024) may have influenced the pooled estimates, due to the variations in questions used to assess screen time across the included studies, and the uncertain validity and reliability of the screen time questionnaire, leading to varying estimates.

Given the dearth of research evidence from the UK, survey evidence might provide some useful insights but there is also very little survey evidence from the UK. The UK screen regulator OfCOM publishes surveys of screen behaviour in children periodically and the 2024 survey (data collected in 2023) found increasing access to screens in UK 3-4 year olds: 22% had their own mobile; 84% were online.

(OFCOM, 2024). With a high proportion of children experiencing low adherence to the screen time guideline, it is important to investigate the factors contributing to this, particularly given the limited evidence of parental perceptions and influence on guideline adherence among children aged 3–4 years in the UK. Although the UK does not have specific national guidelines for screen time in young children, current recommendations broadly align with the World Health Organization 24-hour movement guidelines, which suggest that children aged 3–4 years should engage in at least 180 minutes of physical activity per day, achieve adequate sleep, and limit sedentary screen time to no more than one hour (WHO, 2019). Despite these recommendations, evidence from the UK indicates that adherence to movement behaviour guidelines remains low. For example, studies have shown that fewer than half of young children meet recommended limits for screen time, with screen exposure beginning early in life and increasing rapidly during the toddler and preschool years (McNeill et al., 2019; Pearson et al., 2018). Evidence from a longitudinal study in the UK suggests that sedentary behaviour and screen time begin early in life and often exceed recommended limits with about 75% of children exceeding recommended screen time limits by 12 months of age, and screen time increasing rapidly throughout early childhood (Barber et al., 2018).

In addition to sedentary behaviour, physical activity levels among young children in the UK are also suboptimal. Research suggests that a relatively small proportion of children aged 2–4 years meet the recommended levels of daily physical activity, highlighting a broader pattern of low adherence across movement behaviours (Hesketh et al., 2017; Griffiths et al., 2016). These findings suggest that while international guidelines provide a useful framework, many young children in the UK are not meeting recommendations across multiple movement behaviours. This reinforces the importance of examining sedentary behaviour, particularly screen time, as a key contributor to children's overall movement patterns and health outcomes in the early years.

Based on the socio-ecological framework mentioned earlier in the thesis introduction chapter, children's behaviours are the result of interacting influences across multiple levels including individual, interpersonal, organisational, community, and policy contexts. At the individual level, children's

preferences for screen-based entertainment and digital media have increased in recent years with the widespread availability of tablets, smartphones and other mobile devices. At the interpersonal level, parents play a central role in shaping young children's screen exposure by regulating access to devices, setting household rules, and modelling their own media use behaviours. For instance, qualitative research by Hinkley et al. (2018) with parents showed that caregivers often perceive both benefits and risks associated with screen use, including educational value and opportunities for relaxation, but also concerns regarding habit formation and reduced physical activity (Hinckley et al., 2018).

Beyond the household, organisational and community environments in Scotland and the wider UK also play an important role in shaping children's screen time. Early learning and childcare settings influence children's daily routines and opportunities for active play, reflecting national policy commitments to prioritise play and wellbeing (Scottish Government, 2025). However, wider environmental factors- including neighbourhood safety, access to green space, and seasonal weather- can limit opportunities for outdoor activity. In the UK, there is evidence to suggest that many children experience barriers to outdoor play, with around one-third not playing outside after school and inequalities linked to local environments and deprivation (Archer & Kelly, 2025). In Scotland specifically, children's sedentary leisure time has increased in recent years, with estimates of up to 3.8 hours per weekday and over 5 hours at weekends (Scottish Government, 2024). These structural and environmental constraints may increase reliance on indoor and screen-based activities for entertainment or childcare, particularly where safe and accessible outdoor opportunities are limited.

At the policy level, although the UK does not have specific national guidelines for screen time in children, as mentioned earlier, national movement behaviour recommendations and public health guidance provide frameworks for supporting healthy development in early childhood. However, research in the UK suggests that awareness of sedentary behaviour guidelines among parents is often limited, and reducing screen time may not be perceived as a priority compared with other child health behaviours such as sleep or physical activity (Hesketh and Janssen 2022). This highlights a potential

gap between public health recommendations and parental understanding or implementation of these guidelines in everyday family life in Scotland.

Taken together, these multiple levels of influence demonstrate that children's screen time are shaped by a complex interaction of personal characteristics, family dynamics, environmental opportunities, and broader policy contexts. Understanding these influences through the socio-ecological lens is therefore important for identifying the barriers and facilitators that parents experience when attempting to manage their children's screen time. Such insights can inform the development of multi-level strategies aimed at promoting healthier movement behaviours in early childhood.

As digital screen devices evolve and are present in most households in high-income countries (Brooke et al., 2020), their influence on children's development can be seen across all levels of the socio-ecological model. Family and its role in socialisation may play a fundamental role in children's screen time across all levels and is therefore of great importance when seeking to understand children's screen time at home. According to social cognitive theory, children adopt behaviours by observing their surroundings; hence, their screen-related behaviours could be significantly influenced by the prevailing behaviours, perceptions, and attitudes within the family (Lin, 2022). Parents play a fundamental role in children's upbringing and development and have considerable influence on their children's movement behaviours, including screen time, with the family environment also serving as a primary ecosystem supporting children's growth and development (Stienwandt et al., 2022; Smith et al., 2010; Ling et al., 2023; Hinkley et al., 2014; Vaughn et al., 2013; Loprinzi et al., 2010).

Studies have shown that children from households with higher parental educational attainment may have lower levels of screen time, as they are more likely to set limits on their screen time and engage their children in alternative activities (Taveras et al., 2015). This may possibly be because parents with higher educational levels are more likely to be aware of the recommended screen time guideline and the potential risks of excessive screen time, leading to stricter regulations on their children's screen time, while those with lower education may lack awareness of guidelines or effective strategies to

regulate screen time, leading to greater reliance on screens as a form of child engagement (Ke et al., 2023).

Some studies have also shown that parental stress and exhaustion contributes to the increasing risk of high levels of screen time in the early years (Okely et al., 2023) while other studies have attributed children's screen time to parental screen time, parental self-efficacy and screen time rules and restrictions set by parents (Goncalves et al., 2019; Lauricella et al., 2015; Jago et al., 2015). A systematic review by Xu et al. (2015) on parental influences on physical activity and screen time among young children (6 years and younger) suggested that reducing parents' own screen time can lead to decreased child screen time. The review also highlighted parental practices and parenting styles as modifiable correlates to reducing screen time in children (Xu et al., 2015). A cross-sectional study by Kracht et al. (2021) that evaluated the association between household chaos and movement behaviours of children aged 3.0-5.9 years, and the role of family routines in this relationship, suggested that parental rules and routines around screen time protected their children from excessive screen time during the COVID-19 outbreak (Kracht et al., 2021). Another cross-sectional study by Halpin et al. (2021) also reported that dysfunctional parenting styles may be associated with greater screen time-related child behaviour problems among children 0-4years.

A recent systematic review by Chong et al. (2023), which explored perceptions of parents on children and adolescents' screen time, revealed the differences in opinions about screen time among parents. This qualitative meta-synthesis provided insight into the varied reasons parents promote screen time, parental attitudes towards screen time and strategies and approaches to manage screen time (Chong et al., 2023). However, this review, which included children and adolescents between the ages of 0 and 15 years across predominantly Western countries, may be limited as views from parents included in the review may not be representative of different SES or multicultural societies, highlighting the need for future studies to include views from parents with different cultural backgrounds.

In previous qualitative studies (Bentley et al., 2016; Knowles et al., 2015; Carson et al., 2014; De Decker et al., 2012), parents of children aged 2-6 have expressed mixed views on their children's screen time.

While some had concerns about the impact of screen time on their children's health, others felt it was an important and valuable educational tool. However, participants of these studies have mostly been from middle to high-income families, which may not be representative of those from low-income families. Again, as mentioned earlier, the systematic review by Chong et al. (2023) also highlighted the need for future studies that explore perceptions of children's screen time, including families from low-income settings. It is therefore important to explore parental views on barriers and facilitators to meeting the screen time guideline from families across all socio-economic groups, and to help promote adherence to the screen time guideline in 3-4-year-olds.

To our knowledge, no previous research has examined parents' perceptions of the screen time guideline and whether these perceptions differ between those from low- and high-income families or between those whose children meet or do not meet the screen time guideline in Scotland. The aims of this study were therefore to 1) better understand parents' perception on barriers and facilitators to meeting the screen time guideline and 2) examine the difference in perception between those who meet and do not meet the guideline.

4.3 Methods

4.3.1 Study Design

This is a mixed methods study using both qualitative and quantitative data. The quantitative data will inform the qualitative part of the study to help provide a better and deeper understanding of the adherence to screen time guideline in children aged 3-4 years old.

4.3.2 Quantitative Study

1) Participants

For the quantitative part of this study, an exploratory sample of 56 children aged 3-4 years was recruited from nurseries and other childcare settings across Scotland. Recruitment aimed to engage a larger number of participants across multiple community settings; however, recruitment proved challenging. Multiple recruitment strategies were used, including distribution of flyers through nurseries, churches, and community playgroups (e.g., Bookbug sessions), online advertising using social media and word-of-mouth within the Glasgow area. Despite these efforts, the final sample consisted of 56 participants, which may be due to barriers such as parental time constraints, concerns about device wear protocols, and competing family commitments, as parents were required to document monitor wear and non-wear times. This sample may not be a representative of the wider Scottish population and therefore considered exploratory in nature as it aimed to generate preliminary insights into screen time in 3-4 year olds, with the same participating group providing contextual understanding and explanation of the quantitative findings. Interested parents/guardians were given an information leaflet about the study (either a hard copy or via a web link). To be included, participants must live in Scotland, and their child must be 3 to 4 years old and have no medical condition. Participants whose parents reported any medical conditions were not included in the analyses of the study.

2) Procedures

Quantitative data for the study were collected in two sessions. The first set of data was collected between October 2018 and March 2020 (pre-COVID-19 period), and the second set was collected between June 2022 and March 2023 (post-COVID-19 period). Once interested families were identified,

parents/guardians of participants were asked to provide consent by signing the parent information sheet and completing a parent questionnaire developed from the SUNRISE parent questionnaire (either online or hard copy) (Okely et al., 2021).

3) Ethical approval

Ethical approval was obtained from the Department of Psychological Sciences and Health Ethics Committee at the University of Strathclyde, and informed consent was obtained from parents of all participating children, with children providing assent to participate in the study.

4) Quantitative Measures

Anthropometrics/ Parent Demographic Characteristics

Parents were asked to provide information on their child's weight (in kg) and height (in cm) via the online/paper form questionnaire. The children's weight and height were measured using a digital scale (SECA 878) and a portable wall-mounted stadiometer (SECA 213), with participants wearing light clothing and no footwear. Measurements were recorded to the nearest 0.1 kg and 0.1 cm, respectively. Body mass index (BMI) was determined by dividing weight in kilograms by height in meters squared. Classification of BMI categories was based on the World Health Organization's reference standards (WHO, 2026). The questionnaire also asked for child and parents/caregivers' names, address, dates of birth, sex, education level, annual household income and cultural background to be reported.

v

Socio-Economic Status (SES)

SES was measured using the total household income. Parents were asked to report if their household income was less than £16,000 per year, between £16,000 and £25,000 per year or more than £25,000 per year. Low-income families in Scotland are defined as those earning less than 60% of the national median pay, adjusted for household type (Scottish Government, 2024). In the present study low income was therefore defined as less than £25,000 per year (Scottish Government, 2024).

Physical activity and sedentary behaviour

Physical activity and sedentary behaviour were measured using ActiGraph accelerometers (GT3X+). The ActiGraph is a widely used activity monitor shown to have acceptable validity and reliability in this age group (Puyau et al., 2002; Smith et al., 2020). This device produces output in the form of activity counts, and provides information about the intensity of physical activity, the higher the counts the greater the intensity. Participants wore the accelerometer on their hip by an elastic waist belt under their clothing for 7 consecutive days, except when they were bathing, swimming. The non-wear times of the monitor were recorded by parents/guardians on the log sheet provided daily alongside the participants sleep and wake times and defined by the monitors as a period of at least 60 consecutive minutes of zero counts. The accelerometers were initialized to collect acceleration data on three axes at a sampling rate of 100 Hz and were downloaded using ActiLife software 6.12.1 (ActiGraph Pensacola, FL, USA). Data were initially saved as GT3X files, and later converted to the raw .csv file format for export and analysis. The epoch duration was set to 15s, which has been shown to be more accurate for the assessment of the spontaneous and intermittent activities of the young children. (Vale et al., 2009). Epochs were defined as sedentary behaviour, light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) when recorded counts are less than 200 counts/15 s, between 200 and 799 counts/15 s and >800 counts/15 s respectively. Participants with at least 3-days of valid data will be included in the analysis. A valid day was defined as having at least 10-h per waking day of accelerometer data.

Sleep

Participants sleep time was reported using a parent/guardian report. For sleep duration, parents were asked to report the number of hours of sleep their child get in a typical 24-hours day (including naps), whether they had consistent bedtime and wake-up times, and how long their children nap (if they do at all).

Screen Time

Participants' screen time was assessed via a parent questionnaire, developed from the SUNRISE international parent questionnaire (Okely et al, 2021). Parents/guardians were asked to report how much time their child spent using screens -such as watching TV, using the computer, or playing other video

games —while sitting or lying down over 24 hours during the past 5 days. Although the validity and reliability of the questionnaire developed using the SUNRISE parent questionnaire and used in this present study is unknown, it is practical and culturally appropriate (can be used in both HICs and LMICs), in line with the WHO 2019 movement guidelines for the corresponding age group. It is also known to have face validity, e.g., in identifying between-group differences associated with the level of country economic development (Nystrom et al., 2020; Hossain et al., 2021). Hence, in the absence of a well-established, validated, and reliable questionnaire for screen time in 3-4-year-olds, the SUNRISE international questionnaire was used.

Compliance with the Screen Time Guideline

Participants met the screen time guideline if they were reported to have spent ≤ 1h/day on screen time a day (Tremblay et al., 2017; WHO, 2019) as measured by the SUNRISE Study Questionnaire.

4.3.3 Qualitative Data

Participants

Participants for the qualitative study were recruited during the second phase of the quantitative data collection (June 2022 – March 2023). In total, 19 participants agreed to take part in the qualitative part of the study. Both high- and low-income families were included in the study.

Procedures

The Asynchronous Remote Communities method (ARC; MacLeod et al., 2017) was used to collect the qualitative data for this study. This method involves researchers engaging participants in an online-based focus group. The ARC method is recommended for reaching seldom heard and hard-to-reach communities, as it eliminates barriers such as travel costs and the difficulties associated with face-to-face focus groups (MacLeod et al., 2016, 2017). For the present study, once quantitative data collection was completed, participants who consented to take part in the online qualitative study were invited to a closed Facebook group and asked to complete weekly activities. Three focus groups, each with a

minimum of 6 and a maximum of 8 families, were enrolled in a discussion group. The size of the groups was set to 6 to 8 to ensure participants had ample time to contribute and share their detailed views, while also being efficiently managed by the research moderator (MacLeod et al., 2016).

As data for the qualitative study was retrieved from a larger study by Dalziel et al. (2023) on the three movement behaviours, the researcher in this present study was not the moderator of the group. However, the researcher was invited and granted access to the Facebook group as an observer and was able to monitor participant engagement and discussion throughout the data collection period. The ARC ran for six weeks, during which two structured activities were posted each week, resulting in a total of twelve discussion prompts. Parents and guardians were invited to respond to the prompts by posting comments, sharing reflections, and engaging with the responses of other participants. The discussion prompts were designed to explore parents' perspectives on the movement behaviour guidelines among 3–4 year olds. For example, parents were asked to reflect on whether the recommended targets for children's movement behaviours were achievable and realistic within their family context (See Appendix 5 for interview activities). In addition, participants were provided with individualised activity profiles derived from the quantitative data collected in the study. Parents were invited to comment on their reactions to these profiles, including whether the results were surprising or aligned with their expectations, and whether they would consider making changes to their child's behaviours. Further prompts explored the challenges parents face in meeting screen time recommendations, factors that might facilitate adherence, and suggestions for strategies or interventions that could support families in reducing sedentary screen use. Parents/guardians were allowed to post pictures as part of the activities if they wanted. In cases where parents/guardians were not interacting in the online discussion, researchers sent personal reminders by tagging them on the post or by sending gentle reminders via email. The asynchronous nature of the platform allowed participants to contribute at times convenient to them, which is particularly beneficial for parents of young children. All contributions posted within the discussion forum were captured with data on the screen time guideline retrieved and analysed using reflexive thematic analysis.

4.3.4 Statistical Analysis

Quantitative Data

Exploratory statistical analyses were conducted using the SPSS Statistics for iOS version 29.0 (IBM Corp, Armonk, NY). Only participants with valid data on screen time were included in the analysis. Descriptive statistics (mean, standard deviation) were computed for continuous variables, and frequencies were reported for categorical variables. The differences in demographics between boys and girls were examined using an independent t-test, and the Pearson's chi-square test was used to examine differences in the proportion of children meeting the guideline between boys and girls and pre- and post-COVID. Given the number of participants involved, the prevalence estimates and between-group differences in prevalence estimates provided in the quantitative section of this thesis chapter are exploratory and should be tested in larger, more representative samples. Statistical significance was set at $p<0.05$.

Qualitative Data

Qualitative data were analysed using Braun and Clarke's reflexive approach to thematic analysis, which includes six phases (Braun & Clarke et al., 2015). Data were anonymised, transcribed, organised and analysed using NVivo software (Version 2020). Thematic data analysis from the focus group discussion was conducted (Braun & Clarke, 2015) to identify relevant themes regarding parents' views on the barriers and facilitators to meeting the screen time guideline. The thematic analysis approach was adopted, as it is a widely accepted, robust, and systematic method for coding, identifying, and interpreting patterns in qualitative research studies (Braun et al., 2016; Braun & Clarke, 2014). It also allows key details, experiences, and opinions of participants to be highlighted in their own words, which is relevant for extracting and analysing data on parents' perceptions (Braun et al., 2014; Braun & Clarke, 2014; Javadi & Zara, 2016).

Data analysis was performed independently by NK and was checked by XJ. Data were first transcribed by AD. Following transcription, NK familiarised with the data, after which the data were exported to NVivo (Version 2020), where keywords, phrases, and quotes relevant to the aims of this study were identified. Codes and themes were then generated and independently reviewed by XJ to ensure the thematic analysis was thorough and the themes accurately represented the collected data. NK and XJ agreed that all six phases of the approach had been duly completed, and an agreement was reached via a reflective discussion on interpretation (Yardly & Bishops, 2017). Differences between families whose children met the screen-time guidelines and those who did not, as well as between higher- and lower-income groups were identified.

4.4 Results

4.4.1 Quantitative Study

Overall, 56 parents of children aged 3-4 from low-, middle-, and high-income families in Scotland consented to participate in the study, with 43 included in the analysis. The mean age of participants was 4.2 years (SD = 0.5 years). Of the 56 participants, thirteen participants were missing data on screen time. In the exploratory analysis, the proportion of children meeting the WHO screen time guideline was 40% (n=17). Table 1 below shows the descriptive characteristics of participants, and the amount of time spent in screen time (mins/day), stratified by sex.

Table 1. Descriptive Characteristics of Participants

	Total (N=43)	Boys (n=23)	Girls (n=20)	P-value
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	
Age[a] (years)	4.19 (0.6)	4.32 (0.5)	4.04 (0.7)	0.254
WAZ[b] (Kg)	0.51 (1.1)	0.41 (1.0)	0.62 (1.2)	0.852
HAZ [c] (cm)	0.15 (1.3)	0.12 (1.3)	0.18 (1.2)	0.656
BAZ [d](kg/m)	0.58 (1.2)	0.43 (1.2)	0.75 (1.2)	0.717
Screen time[e] (min/day)	107.00(58)	113.00 (55)	100.00 (62)	0.570
Sedentary behaviour[f] (min/day)	546 (656)	442 (146)	664 (947)	0.100
Light physical activity[g](min/day)	253 (75)	256 (98)	249 (38)	0.031
Moderate-vigorous physical activity[h](min/day)	67 (3.0)	75 (35)	58 (19)	0.008
Sleep[i] (hrs/day)	11 (0.7)	11 (0.7)	11 (0.8)	0.841

N- total number of participants; SD- Standard deviation; WAZ- weight (Z-scores); HAZ- Height (Z-scores); BAZ- BMI (Z-scores); 8 participants missing data on sex; [a]n= 43; [b]n= 42; [c]n=43; [d]n=42; [e]n=43; [f]n=43; [g]n=43; [h]n=43; [i]n=43; Differences between sex tested using an independent t-test; Statistical significant set at $p < 0.05$.

The proportion of children meeting the WHO screen time, restraint and the sedentary behaviour guidelines are shown in table 2 below. Overall, only 12% (n=5) of children met the sedentary behaviour guidelines, while 40% (n= 17) and 37% (n= 17) of children met the screen time and restraint guidelines

respectively. No statistically significant differences were found between boys and girls who met the overall sedentary behaviour guidelines or individual screen time and restraint guideline.

Table 2. Exploratory analysis of proportion of participants meeting the sedentary behaviour guidelines stratified by sex.

	Total, n (%)	Boys, n (%)	Girls, n (%)	p value
Screen time guideline[a] (≤60 min screen time per day)	17 (40)	7 (30)	10 (50)	0.191
Restraint guideline[b] (≤60 min restraint time at a time)	17 (37)	10 (43)	7 (30)	0.359
Sedentary behaviour guideline[c] (≤60 min screen time per day and ≤60 min restraint at a time)	5 (12)	3 (13)	2 (10)	0.759

Differences between sex tested using Chi-square test. [a]n=43; [b]n=46; [c]n= 43; Statistical significant set at $p < 0.05$.

The proportion of participants meeting the guidelines is shown in the table 3 below.

Table 3. Proportion of participants meeting the individual guidelines, combination, and the overall guidelines.

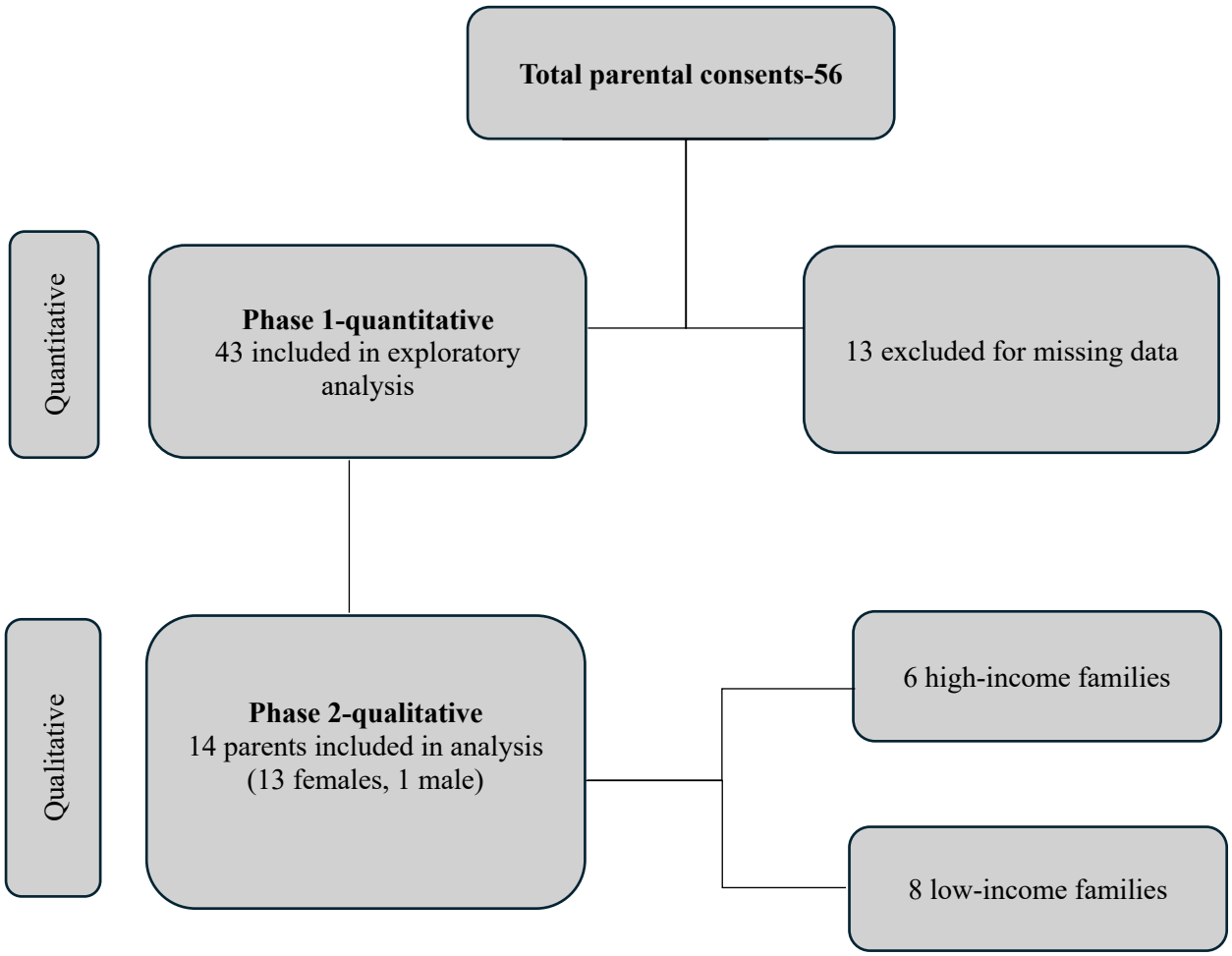
Individual guidelines	**N**	**Meeting % (n)**	**Not meeting % (n)**
Physical activity	43	58 (25)	42 (18)
Sedentary behaviour (screen time and restraint)	43	12 (5)	88 (38)
Sleep	43	95 (41)	5 (2)
Combination of guidelines			
Physical activity and sedentary behaviour	43	12 (5)	88 (38)
Physical activity and Sleep	43	54 (23)	46 (20)
Sedentary behaviour and Sleep	43	12 (5)	88 (38)
All three guidelines	**43**	**9 (4)**	**91 (39)**

N- total number of participants; n- number of participants

4.4.2 Qualitative Findings

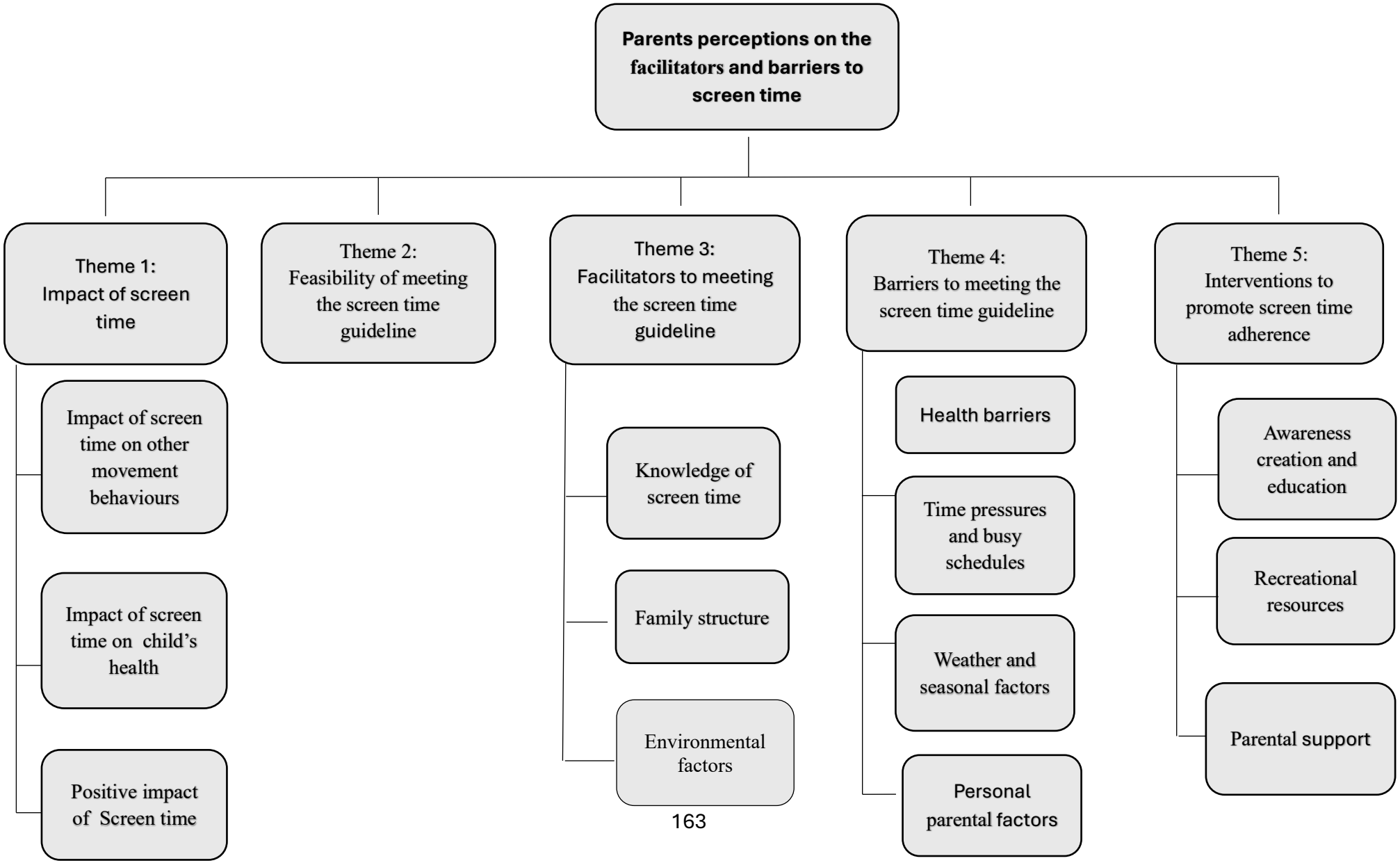
Overall, 23 participants were invited to the study; 19 agreed to take part, and 14 (13 female and 1 male parent) actively engaged in the focus groups and provided data for analysis. Six participants were from high-income families, and 8 from low-income families (see Figure 1). Participants' children included 6 boys and 9 girls (one family had twins), aged 3-4 years. The mean age of parents and children was 36.5 years (SD=6.1) and 4.1 years (SD=0.7), respectively.

Fig 2. A CONSORT flow diagram showing the number of participants included in both qualitative and quantitative studies



The thematic analysis identified five main themes and 10 sub-themes. The five main themes were: (1) impact of screen time; (2) feasibility of meeting the screen time guideline; (3) facilitators to meeting the screen time guideline; (4) barriers to meeting the screen time guideline; and (5) promotion of screen time adherence. These themes, their corresponding sub-themes, and quotes are presented in Fig. 2 below.

Fig 3. Summary of themes and subthemes identified



Theme 1- Impact of Screen Time

a) Impact of Screen Time on Other Movement Behaviours

Overall, most participants felt that screen time was linked to and interacts with other movement behaviours. Some participants reported that excessive screen time negatively affected sleep quality, and that sleep quality improved immediately on days when their children were without screens. For example, parents stated that

"I know that screen time, used before bed, can negatively impact sleep quality at night" (BD001; High income, did not meet screen time guideline).

"We also limit her screen time before bed just to let her brain quiet down, along with her body. If those two things (screen time and physical activity) are out of sync, sleep is also difficult." (BD012; low income, did not meet screen time guideline).

Another parent shared that their child's sleep pattern improved after screen time was removed from their routine.

"When my daughter was about 18 months old, I got rid of our TV because…. I felt like she wanted to watch it too much. Although she complained for a few weeks, her sleep improved immediately" (BD009; Low income, met the screen time guideline).

b) Impact of Screen Time on Children's Health

Participants shared views on how they think screen time affects their children's development and behaviours. For example, some participants shared that their children became overstimulated by screen time, which was not great for their development and behaviour, as they would become "angry easily" when the screen gadgets were taken away.

"We found that when our children watched programs, their behaviour was not as good as when they did not. They would become angry much more easily" (BD011; Low income, met the screen time guideline).

Another parent shared that screen time caused overstimulation in their child:

"...he may be overstimulated by screen time... I do not think it is particularly great for development other than for learning…" (BD005; Low income, did not meet screen time guideline).

c) Positive Impact of Screen Time

However, some participants reported that screen time was important for their child because of the many educational games/programs that encourage them to ask questions and help them become tech-savvy, as shared by one parent.

"I feel that screens have their place and that it is important for our children to be tech savvy…" (BD011; Low income, met the screen time guideline).

Others also shared that screen time could be used as a relaxing tool for their children and the family.

"I find sometimes TV is needed to relax a bit…" (BD006; High income, did not meet screen time guideline).

Theme 2: Meeting the Screen Time Guideline

Participants whose children did not meet the screen time guideline shared that they did not know of the screen time guideline, and that meeting the screen time guideline of 1 hour a day was quite a challenge and a lot to ask of the children.

"I knew about the sleep (guideline) one but not about the other 2 (screen time and physical activity guideline) …. Most days the girls will have more than 1 hour of screen time, so not achievable for us" (BD019; Low income, did not meet screen time guideline).

Some participants also felt the screen time guideline was not realistic and quite harsh. One parent shared that:

"I feel the screen time target is pretty harsh as long as it is not staring at a screen constantly, i.e., doing other activities at the same time, I think it is okay to go slightly over this" (BD003; Low income, did not meet screen time guideline).

Other parents, on the other hand, said that meeting the screen time guideline was achievable, but that the target could not be achieved every day.

"I knew about the recommendations, and I do think they are achievable, although maybe not every single day" (BD007; High income, met the screen time guideline).

However, some participants explained that although their children sometimes exceeded the screen time guideline, they did so while engaging in other activities, such as eating or working on puzzles, hence they had no issues in those situations. Others also said that so long as they use it for educational purposes, they did not have concerns when their children exceeded the guideline recommendation. However, one participant said that meeting the 1-hour screen time per day was achievable as they could monitor and control their children's screen activities:

" Again, max 1-hour screen time is achievable as we can monitor and control it." (BD011; Low income, met the screen time guideline).

Theme 3- Facilitators to Meeting the Screen Time Guideline

Although some participants mentioned that their children exceeded the screen time guideline, they echoed some positive influences that could facilitate meeting the screen time guideline.

a) Knowledge of the Screen Time Guideline

One parent whose child met the screen time guideline shared that the knowledge of the existence of the screen time guideline was a contributing factor that helped enforce some boundaries and limitations to their children's screen time, as they did not want to make a choice that would be detrimental to their children's development:

"But for... screen time, the greatest contributors to achieving those guidelines for me is probably the knowledge of the guidelines and holding the boundaries most of the time with my son (which is hard but serves both my/our sanity and his meeting of the guidelines)"- (BD007; High income, met the screen time guideline).

Some parents highlighted that being strict with the times they allow their children to use screen time helped their children adhere to the guideline recommendation:

"...screen time is helped by being strict and not allowing him to have an iPad or tablet, but he likes to watch a film on TV" (BD005; Low income, did not meet screen time guideline).

b) Family Structure

Some parents highlighted how their family structure helps them meet the screen time guidelines. For example, some parents shared that having more than one child helped in keeping screen time at bay, as they tend to play with other siblings:

"When we are home, BD022 will happily play with his big sister while I do housework, etc., so we do not need screen time most days" (BD022; Low income, did not meet screen time guideline).

Another parent also shared that having an only child was somewhat helpful, as it was easier to engage one child in activities, which in turn would limit screen time, rather than engaging multiple children:

"I imagine that if I had more than one child, I would be more reliant on screens and would be less capable of getting each child to activities… and I think this would be more challenging if we had more than 1" (BD007; High income, met the screen time guideline).

c) Environmental Factors

Parents whose children met the screen time guideline said they were fortunate to have an active lifestyle and live in an environment with excellent access to parks, pools and recreational areas, which promoted an active lifestyle and helped keep their children's screen time at bay. One parent shared that:

"Probably a big help is that my husband and I largely lead a lifestyle/live in an environment that makes the 24-hour movement guidelines achievable" (BD007; *High income, met the screen time guideline).*

Theme 4- Barriers to Meeting the Screen Time Guideline

a) Health Barriers

One of the barriers identified by parents was the never-ending sickness and health issues that prevented their children from meeting the screen time guideline. One parent shared that:

"...the never-ending sickness – that is definitely a barrier that tends to agitate all three behaviours (in our family, sickness = more screen time)" (BD007; High income, met the screen time guideline).

In line with this, another parent also said that:

"The amount of constant bugs certainly has an impact!" (BD008; High income, did not meet screen time guideline).

Overall, some parents reported that on days when their children were not feeling well or were sick, they used screens more because they were unable to engage in much physical activity.

b) Time Pressures/Busy Schedules

Most participants identified time and busy schedules as the most common challenge for the children meeting the screen time guideline. Parents mentioned they use screens to keep children busy while they get work or household chores done. For instance, a parent shared that:

"A barrier for screen for me is due to working full time, and then when I need to get jobs in the house, I use it to keep her occupied" (BD008; High income, did not meet screen time guideline).

Another parent also shared that:

"I think our main barrier is time…Often using screen time to try and get tidying etc done" (BD006; High income, did not meet screen time guideline).

c) Climate/Seasonal Factors

For others, the weather and seasonal changes also increase their children's screen time, as they are unable to play outside on extremely cold, rainy days and thus resort to screens as the easier option to keep them busy. One parent said

"The wet weather has been a barrier for getting out and about and... Sometimes for my own mind it is easier to give them a tablet or let them watch TV just so I can get stuff done around the house without them fighting" (BD019/020; Low income, did not meet screen time guideline).

Another parent also shared that:

“a wet summer limiting options for outdoor play…. Sometimes it is the easy option to allow for screen time to keep her occupied…” (BD018; Low income, did not meet screen time guideline).

Parents also shared that the lack of safe indoor facilities for children to engage in during unfavourable weather conditions was also a hindrance to meeting the screen time guideline.

“Also, we are very lucky where we live to get a lot of outdoor activity however, lack of indoor safe spaces/facilities for infants stop us getting out at times especially due to the amount of bad weather we get” (BD003; Low income, did not meet screen time guideline).

d) Personal Parental Factors

Some parents shared that they gave their children screen time so they could have some time for themselves. For instance, a parent shared that:

"CBD003’s biggest chunk of screen time is in the morning, anything for an extra snooze for mummy or daddy!" (BD003; Low income, did not meet screen time guideline).

Themes 5- Interventions to Promote Screen Time Adherence

a) Awareness Creation and Education

Overall, most parents shared the view that raising awareness of the existence of the screen time guideline was very important, as some participants stated they did not know about it. For instance, one parent said,

“I was not aware of what the structure should be for screen…., but more awareness, even workshops for parents and kids, would definitely be useful" (BD003; Low income, did not meet screen time guideline).

Along with making the screen time guideline known, some parents said that educating parents on the importance of limiting screen time and the health risks of excessive screen time was key to ensuring that parents make the best decisions in promoting a healthy lifestyle. In line with that, one parent suggested that:

"I think making parents aware of the effects that screen time has on children's brains is important as in my experience so many of them think they are doing the right thing by letting them play educational apps, but do not realise how addictive screen time is and what it is doing to their child's brain" (BD011; Low income, met the screen time).

b) Recreational Resources

Some parents suggested that facilities that provide indoor activities, such as soft plays and pools, should be made accessible and affordable to allow parents to engage their children in active play on days when extreme weather conditions prevent outdoor play, and to reduce children's screen time. One parent said,

"More affordable indoor play opportunities would make a big difference" (BD022; Low income, did not meet screen time guideline).

If some of these community resources were more affordable, parents could drop off their children so they could have more active time without screens.

c) Parental Support

Some participants suggested that parents can help develop strategies to engage more with their children, e.g., chatting with them during dinner instead of watching TV, and coming up with solutions that fit well with their lifestyle. One parent highlighted that:

"I think there is heaps of value in promoting a healthier lifestyle without being direct about the guidelines and perhaps emphasising some other benefits. E.g., by encouraging a family to enjoy their

evening meal at a dinner table, which is also a no-screen zone… I think a big part of building a child's best day is by participating in it as much as your time/capacity allows" (BD007; High income, met the screen time guideline).

Parental perspective based on guideline adherence

Some differences in perceptions were observed between parents whose children met the screen time guideline and those whose children did not. For example, this study found that parents whose children met the screen time guideline had prior knowledge of the guideline, which may have helped them set boundaries on screen time and encourage adherence. One parent said,

"On a surface level, I knew about these (guidelines)... Again, max 1-hour screen time is achievable as we can monitor and control it" (BD011; Low income, met the screen time guideline).

Another parent also said,

"We do not have regular screen time… I knew about the targets (guidelines), the one I mainly pay attention to is the sleeping target" (BD009; Low income, met the screen time guideline).

No marked differences in perception were observed between high- and low-income families.

4.5 Discussion

4.5.1 Main Findings

This study explored parents' perceptions of barriers and facilitators to meeting the screen time guideline for 3-4-year-olds in Scotland. Exploratory findings from the quantitative analysis suggested low adherence (40%) to the screen time guideline in 3-4-year-olds in Scotland. Findings from the qualitative analysis in this present study show that busy schedules, health issues, climate/seasonal changes and personal parental factors such as giving screen devices to children to allow parents have a self-care moment or an extra snooze, were perceived barriers to meeting the WHO screen time guideline for 3-4 years. Facilitators to meeting the screen time guideline, as highlighted by parents in this study, include knowledge of the existence of the screen time guideline and family structure (i.e. how multiple children in the family encourage active play and reduce screen time).

The qualitative findings can be further interpreted using the socioecological model to understand how multiple levels of influence shape children's screen time behaviours. At the intrapersonal level, parents highlighted how children's individual behaviours and daily routines were affected by screen time particularly the perceived impact of screen time on other movement behaviours such as sleep and opportunities for physical activity. At the interpersonal level, parental decision-making and family routines played an important role in shaping children's screen exposure, with parents describing challenges in limiting their children's screen time due to busy household and work schedules, and the use of screens for educational purposes. At the community level, environmental factors such as availability and accessibility to playgrounds (to encourage active play) and soft plays and recreational centre (for during colder and wetter periods when outdoor play opportunities were reduced) within communities were identified as barriers to limiting screen time. At the organisational level, parents emphasised the importance of access to affordable childcare educational centres like nurseries may provide opportunities for children to remain active, particularly when parents have to engage in their busy work schedules. Finally, at the public policy level, parents highlighted the need for greater awareness and dissemination of screen time guidelines, suggesting that improved communication of these recommendations could support parents in making informed decisions about their children's

screen time. Together, these findings illustrate how influences across multiple levels of the socioecological framework interact to shape screen time behaviours in early childhood.

Most parents recommended raising awareness of the screen time guideline and educating parents about the harms of excessive screen time on health to enhance adherence to it. Dissemination of the screen time guideline to parents may raise awareness, provide education on the importance of adhering to the guideline, and promote healthy child development in 3-4-year-olds. The lack of awareness of guidelines in a greater proportion of parents in this present study is not surprising, given the rejection of the GRADE-ADOLOPMENT process to develop the screen time guideline for the under-5s by the UK health departments (Reilly et al, 2020). Without national adoption, and dissemination of the proposed guidelines to end users, awareness of the importance of limiting screen time may remain low. Hence, the rejection of the GRADE ADOLOPMENT process, may result in little to no focus on translating the proposed guideline into practical, parent-friendly messaging, embedding them within health, child and early years services. This may not encourage or raise the needed awareness creation among parents and the general public of the WHO screen time guideline in the UK, and may, in a way, contribute to the high levels of screen time in 3-4-year-olds reported in this present study. Studies have shown that several countries, including South Africa and Australia, have made extensive efforts to disseminate the WHO movement guidelines to end users, and despite some constraints, these processes are examples of pragmatic application of the GRADE-ADOLOPMENT approach. Findings from these studies confirm the feasibility and acceptability of culturally appropriate and context-specific community-based dissemination of behavioural guidelines, including screen time (Draper et al., 2020, 2021; Okely et al., 2017). Findings from the current study also suggest a clear need for dissemination strategies and policies aimed at promoting guideline awareness and adherence to minimise the hazardous health consequences associated with excessive screen time among 3-4-year-olds. It is also important to ensure that guidelines are rightly understood and applied by the target audience (Milton et al., 2020). This may encourage parents to adhere to the screen time guideline for optimal benefits for their children.

The perception that screens can be used as an educational resource in the early years is on the rise (Bentley et al., 2015; Carson et al., 2014), and this was supported by findings of the current study. This shift in how parents perceive screen time may indicate a shift in social norms and values placed on screen technologies for children in early years. With digital media and screen device ownership on the rise and widely available for children 3-4 years, there is a tendency for children to engage more in screen time activities, exceeding the guideline of no more than 1 hour per day (McArthur et al., 2022; Kim et al., 2022; Chong et al., 2024). Radesky et al. (2015) acknowledged that although interactive screen time may be valuable for supporting and enhancing children's learning, it should not replace active play and social interactions.

It is also important to highlight the displacement impact of excessive screen time on other movement behaviours, i.e. physical activity and sleep, which provide several benefits to children's health and development (Chen et al., 2020). Excessive time spent on screens may reduce time spent engaging in physical activity or obtaining adequate sleep, as these behaviours lie on a continuum over 24 hours. For instance, a systematic review by Janssen et al. (2020) reports significant associations of excessive screen time with poor sleep in children under 5 years (12/13 studies showed a negative association between screen time and sleep duration) (Janssen et al., 2020).

The COVID-19 pandemic, which affected different aspects of human lives, also impacted the patterns of digital screen time in early years. Studies have shown that adherence to the screen time guideline decreased further during COVID-19. Some systematic reviews (Trott et al., 2022; Bergmann et al., 2022; Brzek et al., 2021) reported a substantial increase in screen time and sedentary behaviour in young children (<5 years) during the pandemic period and after. This was due to increased reliance on digital media for social interaction, entertainment and remote learning purposes. Also, a longitudinal study by Okely et al. (2023) showed an increase in sedentary screen time among children 3-5 years at the height of the COVID-19 pandemic. This increase probably impacted physical activity levels and sleep patterns in children (Kracht et al., 2021).

In raising awareness and publicising the screen time guideline, it is important to understand that environmental influences beyond the individual shape children's health and behaviours. For example, some factors from a higher level of influence, like the lack of legal regulation of screen time, the failure of the UK Health Departments to adopt the WHO 2019 screen time guideline, and some global companies seeking to market digital products and screen time to children and parents, may negatively influence children's screen time. The use of the socio-ecological model to examine the influences of screen time underscores the need for multilevel interventions to address excessive screen time among 3- to 4-year-olds. Effective interventions to reduce screen time should therefore address these various layers of the socio-ecological model, promoting healthier screen time habits through family-based interventions, school policies, community resources, and societal regulations. For instance, programs that prioritise outdoor activities and physical play, creating more community spaces for outdoor activities, and enforcing societal regulations may help limit children's screen time. By targeting these different levels, interventions can create a more supportive environment that might encourage healthier screen time behaviours for children. This means that regulating screen time for 3–4-year-olds at a higher level of influence, including government policies and community resources, might help mitigate the negative impacts of screen time on children's health and development. The socio-cultural, geographical and environmental factors that affect children's screen time may not always be controlled and vary from region to region, such as place of residence, seasons, and government services available (Reid et al., 2016; Paudel et al., 2017). However, it is probably important that stronger guidance, policies and controls are implemented from higher levels of influence to help minimise screen time in 3-4-year-olds.

4.5.2 Comparison with Other Studies

Findings from the present study are similar to those from other qualitative studies that have explored parents' perceptions of the influencing factors of screen time in the early years. For example, the systematic review by Chong et al. (2023) mentioned earlier, which explored views of 1,311 parents on children and young adolescents (aged 0-12 years) screen time, reported differences in parents' opinions on children's screen time as reported in this study. Similar to findings from the review by Chong et al. (2023), some parents in this study felt that excessive screen time impacted other movement behaviours

and negatively affected their children's development. In contrast, others had no concerns about their children's screen time, as it was perceived as used for educational purposes. Chong et al. (2023) also highlighted the need to inform future practice guidelines to educate and inform parents regarding the appropriate use of screens, which was similarly shared by some parents in this present study. The study, which involved 4,836 children (ages 3.5-5.5 years) participating in the multi-centre ToyBox study, showed that parents who set restrictive rules or were mindful of screen time recommendations were linked to reduced screen time among this sample of European preschool children (Miguel-Berges et al., 2020). These findings are consistent with some views highlighted by parents from this present review, where parents shared that setting rules and being strict with their children's screen time helped them meet the screen time guideline.

Similar to finding from this study, some parenting and family studies literature have suggested that parents often rely on screen-based media for pragmatic reasons linked to the realities of everyday family life such as using screens to occupy, calm or soothe children during emotional meltdown, while managing competing demands with work or household tasks. For example, a qualitative study by Bentley et al. (2016) report that parents sometimes use television or mobile devices to help children relax, regulate behaviour, or settle during periods of heightened emotions or fatigue. Again, a cross-sectional study by Emond et al. (2018) examining family environments has found that households experiencing higher levels of daily stress or household chaos tend to report greater child screen time, suggesting that screens may function as a practical coping tool in busy or demanding home contexts. A more recent study by Jusiene et al. (2025) has also noted that parental stress, time constraints, and children's emotional reactivity can increase reliance on screens as a strategy to soothe children or manage behaviour. All these findings highlight that parents use of screens is often shaped by broader contextual pressures rather than simply parental preferences or negligence. Factors such as busy schedules, hybrid working arrangements, childcare demands, illness, and limited opportunities for outdoor play (e.g., due to weather conditions) altogether may influence when and why screens are used within family routines. Understanding these contextual influences is therefore important when developing realistic strategies to support parents in managing young children's screen use.

Contrary to some of the findings from this present study, which highlight negative impacts of excessive screen time on children's behaviours and development, a study conducted with 3-5-year-olds in Malaysia by Singh et al. (2021) reported positive perceptions that screen time improved their children's language. This finding also contradicts existing evidence suggesting that screen time may be detrimental to children's language development, attention, and social interactions (Carson et al., 2015; Hinkley et al., 2014). While screen time has the potential to offer developmental benefits, such as enhanced language skills (Singh et al., 2021), evidence suggests that these positive outcomes are contingent on context and intentional use. For instance, a systematic review and meta-analysis by Mallawaarachchi et al. (2024) reported that when children co-use screens with caregivers, there are positive associations with cognitive outcomes, particularly in language development. This review by Mallawaarachchi et al. (2024) analysed 100 studies involving 176,742 participants aged 0-5 years. These findings underscore the importance of moderate, purposeful screen time, including co-viewing and selecting developmentally appropriate material, to support educational or creative benefits while avoiding potential drawbacks (Radesky et al., 2015; Mallawaarachchi et al., 2024).

4.5.3 Strengths and Limitations

To the author's knowledge, this is the first study that has explored and provided valuable insights into parents' perceptions of the barriers and facilitators to meeting the screen time guideline in Scotland for children between 3 and 4 years old, and also includes low-income families from Scotland. Some strengths of this study include the use of the ARC method, which involves participants completing activities in an online closed Facebook group. This method allowed participants to engage in the focus group discussion from the comfort of their homes, in their own time, without having to travel to a venue at a set time. It also allowed participants to share their opinions and add to others', which could have been missed if individual interviews had been adopted. Although findings from this study reflect the views and opinions of a small number of participants due to the small sample size, participants in the focus group discussion were diverse and included people from different socio-economic backgrounds (high-, middle-, and low-income settings), allowing comparisons between SES groups. The use of a mixed method study approach in the present study to integrate a complementary quantitative and

qualitative research approach enhanced the understanding of the screen time in children. For instance, in this present study, parents' views on the barriers to meeting screen time highlighted underlying reasons for the low adherence to the screen time guideline.

A limitation in the present qualitative study included the issue of social desirability bias (i.e., parents tend to answer in a manner that is favourable to other parents) that may have emerged while discussing the different issues in the groups. Some limitations of the quantitative part of the study include the use of a parent questionnaire to assess screen time in children, for which the validity and reliability have not yet been established and may be prone to over- or under-reporting. However, the use of this questionnaire, developed with the SUNRISE international questionnaire, can be practical and culturally appropriate for the corresponding age group. Also, the small sample size and convenience sampling method used in the quantitative study may limit the generalisability of the study; hence, adherence to the screen time guideline should be replicated in a large cohort of children to verify the levels of adherence reported in this study. Nevertheless, reported estimates are in line with previous studies (Galland et al., 2012; Ofcom, 2015, 2016; Okely et al., 2021; Chong et al., 2024).

4.5.4 Implications for Future Research

It is important that public health stakeholders develop programs and strategies to promote awareness, acceptance, and adherence to the evidence-based screen time guideline. More research is required to further inform the prevalence of meeting the screen time guideline among 3-4-year-olds in Scotland, using a more robust study design with a larger, more representative sample. Future studies could further explore the perspectives of parents from vulnerable and specific groups, such as parents of children with special or developmental needs, as the unique challenges related to parenting efficacy and the use of digital devices for educational and recreational purposes may differ significantly for these groups. Furthermore, exploring the perceptions of other stakeholders within the different levels of the socio-ecological model could offer deeper insights into children’s screen time. This approach may help in designing educational programmes to ensure parents are aware of both the risks and benefits associated with screen time.

In this present study, recruitment of children aged 3–4 years presented several practical challenges possibly due to device compliance in 3-4 year olds and parental engagement, such as completing questionnaires, facilitating device wear, or participating in online discussions, which may increase burden and reduce participation rates. Although multiple recruitment strategies were used including outreach through nurseries, churches, playgroups, Bookbug sessions, online platforms, and word-of-mouth within the Glasgow area, participation remained modest. This highlights the challenges of recruiting families with very young children into research requiring sustained engagement.

One important lesson from this process is the potential value of greater sensitisation prior to recruitment. Sensitisation involves raising awareness about the purpose and importance of the research before actively inviting participation, which may help parents better understand the relevance of the study to their child's development and health. Evidence from qualitative and community-based research highlights that early engagement, clear communication, and trust-building with potential participants can improve recruitment and participation, particularly among families with young children (O'Cathain, 2019; Green & Thorogood, 2018). For example, engaging childcare providers, community groups, and parent networks in advance to introduce the research aims, provide brief informational sessions, or share accessible summaries of the study topic may help build trust and interest among potential participants. Such approaches align with recommendations from recruitment literature, which emphasise that increasing familiarity and perceived relevance of research can reduce uncertainty and enhance willingness to participate (Pope & Mays, 2020). Furthermore, studies focusing on research participation among parents have shown that time constraints, lack of understanding of study purpose, and limited perceived benefit are common barriers to engagement, suggesting that preparatory sensitisation strategies may help address these challenges (Radesky et al., 2020; Chong et al., 2023). Future research involving families with preschool-aged children may therefore benefit from incorporating a sensitisation phase to enhance engagement and participation.

4.5.5 Conclusions

The present mixed methods study examined adherence to the sedentary behaviour guideline in children between 3-4-year-olds in Scotland and explored parents' perceptions on the barriers to and facilitators of meeting the screen time guideline. Findings from the present study suggested that there may be low adherence to the sedentary behaviour guideline, and parents shared views on the potential challenges that may account for the low adherence to the screen time guideline. There were differing views on the use of screen time, ranging from a useful educational tool to negative consequences for their child's health and development. The most predominant recommendation, as highlighted by parents in the present study, is the need to raise awareness of the existence of the WHO screen time guideline. Findings from this present study highlight the need to promote and encourage adherence to the screen time guideline. At a higher level of influence, it is important that public health stakeholders consider the findings from this study when developing policies, strategies, and evidence-based health programs aimed at encouraging healthier levels of screen time in young children. In addition, educating parents about the risks and benefits of high screen time for children may help them make informed decisions about its appropriate use. However, future research is needed to develop and evaluate better educational programs to promote adherence to the screen time guideline and ensure that parents understand the risks and benefits of screen time to promote its safe and rational use.

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Chapter 5: Overall Thesis Discussion and Conclusions

5.1 Chapter Overview

This final chapter summarises the key findings from the three studies presented in the thesis and examines their implications for reducing sedentary screen time among children aged 3-4 years. Furthermore, the chapter will propose future research directions and assess the strengths and limitations of the thesis as a whole. Lastly, it will present the conclusions drawn from the work.

5.2 Summary of Thesis Findings

5.2.1 Summary of Chapter 2 Findings (Study 1)

As noted in chapter 1, the World Health Organization (WHO) identifies early childhood as a crucial period for promoting health and development, emphasising physical activity, sleep, and sedentary behaviour. For 3-4-year-olds, WHO recommends no more than 60 minutes of screen time and limited restraint (e.g., in strollers) per day. However, studies show young children often exceed these limits. Excessive sedentary behaviour may negatively impact motor competence, which is essential for physical development and future physical activity. Motor competence encompasses various motor skills, and contrary to common belief, it does not develop naturally in all children; rather, it results from multiple cooperating subsystems influencing a child's motor skill development (Newell, 1984, 1986; Thelen, 1995). Given its importance, examining the impact of sedentary behaviour on motor competence in early childhood is crucial.

Findings from the review mainly showed negative associations between screen time and fundamental movement skills, gross motor skills, fine motor skills, and object control skills, suggesting that higher screen time may be linked to poorer motor competence. Similarly, habitual sedentary behaviour was negatively associated with locomotor skills, object control, and balance. However, these associations were not statistically significant, likely due to the limited number of studies included in the analysis. The use of vote-counting binomial probability testing, which has low statistical power with small sample sizes, further limits the strength of the findings. The limitations in these findings -particularly

the lack of statistically significant associations between different types of sedentary behaviour and motor competence and the small sample size -highlighted a need for more targeted research with a larger sample. Previous studies often included broad age ranges and used methods with limited analytical power. Focusing specifically on 3-4-year-olds, a critical developmental stage identified in WHO guidelines, allows for a more precise investigation of how screen time and habitual sedentary behaviour relate to motor competence.

5.2.2 Summary of Chapter 3 Findings (Study 2)

To gain a clearer understanding of how sedentary behaviour influences motor competence, it is important to focus on 3-4-year-olds, as this age group differs from both older and younger children. Conducting further research with geographically and culturally diverse groups would shed light on the relationships between various aspects of sedentary behaviour (such as screen time, restraint, and total daily accelerometer-measured sedentary behaviour) and fine and gross motor skills in 3-4-year-olds. This second study, therefore, aimed to explore the associations between sedentary behaviour and fine and gross motor skills in a diverse international sample of 3-4-year-olds. It specifically examined the relationships between 1) screen time and total daily accelerometer-measured sedentary behaviour with motor skills, and 2) adherence to guidelines for restraint, screen time, and overall sedentary behaviour on motor skills. This was a secondary data analysis, using data from the SUNRISE international study, which aims to determine potential correlates of movement behaviours and associations between movement behaviours and health and developmental outcomes in 3-4-year-olds (Okely et al., 2021).

Findings from the secondary data analysis revealed a statistically significant association between screen time (hours per day) and poorer fine- and gross-motor skill performance in 3-4-year-olds, as well as a lower likelihood of meeting developmental milestones. Also, adherence to both screen time and restraint guidelines, individually or together, was associated with improved motor skill scores and increased the odds of being on track with fine and gross motor skill development. Furthermore, the study revealed a concerning low adherence rate of 42% to the overall sedentary behaviour guideline (meeting both screen time and restraint guideline), suggesting that a substantial proportion of children aged 3-4-year old may

be subjected to excessive screen time (more than the WHO recommended time) and spending prolonged time on other sedentary behaviour, thereby increasing the risk of compromised fine and gross motor development. These findings are consistent with findings from a study by Kariippanon et al. (2022), which provides compelling evidence that high levels of sedentary behaviour are prevalent in young children across different cultural and geographic contexts (Kariippanon et al., 2022). The recent comprehensive pooled analysis by Chong et al. (2024), which examined physical activity, sedentary behaviour, and sleep among children from 33 countries, also reported low adherence of 42% of children meeting the screen time guideline across most regions, with substantial variation between countries and socioeconomic groups.

This evidence is consistent with global adherence to the screen time guideline for early years over the past few years, as low adherence reported in this thesis remains common both specifically within countries and globally.

With findings from this second thesis study, which add to the existing evidence of low adherence to the sedentary behaviour guideline and its negative health implications for children's health and development, it is important that the factors contributing to this be explored. This chapter's findings also point to the need to explore parents' perceptions of the barriers and facilitators to meeting the screen time guideline in 3- to 4-year-olds (explored in chapter 4), as parents play a key role and have influence on their children's movement behaviours.

5.2.3 Summary of Chapter 4 Findings (Study 3)

Study 2 from this thesis found that excessive sedentary behaviour may be negatively associated with motor competence, while adherence to screen time and sedentary behaviour guidelines was linked to better motor competence outcomes in 3-4-year-olds. Given the low adherence to the screen time guideline reported in previous research and study 2, it is important to understand parents' perceptions of barriers and facilitators to meeting the screen time guideline, as these perceptions shape children's movement behaviours. Currently, there is limited research on stakeholder views regarding adherence to screen time guideline, particularly among 3-4-year-olds, a group undergoing rapid development and

entering early education. To address this, Study 3 (Chapter 4) explored Scottish parents' views using a mixed-methods approach, aiming to identify supports needed to improve guideline adherence and reduce sedentary time among 3-4-year-olds.

Findings from the exploratory quantitative analysis (n=43) of the study reported that 40% of 3-4 year olds met the screen time guideline in Scotland. The qualitative analysis (n=14) revealed several perceived barriers contributing to this low adherence, including busy schedules, health issues, climate and seasonal changes, and various personal and parental factors. On the other hand, facilitators identified by parents that could help meet the screen time guideline included awareness of the guideline itself and the influence of family structure. There were few notable differences in perceptions regarding screen time between parents whose children met the guideline and those who did not. Parents whose children were within the recommended screen time guideline often had prior knowledge of the guideline. This awareness appeared to empower them to set boundaries around screen time and promote compliance among their children. Interestingly, the research indicated preliminary evidence of no significant differences in perceptions based on income level, as both high- and low-income families showed similar perceptions. These findings provide a potential source of important information for the development of future preventive interventions and policies aimed at reducing screen time in children.

5.3 Learnings from the Overall Thesis

This PhD journey began with a simple but urgent question: how does screen time and sedentary behaviour affect the health and development of young children, particularly those aged 3 to 4 years? At the heart of the project was a dual purpose: not only to investigate the direct impacts of these behaviours on motor competence, but also to understand the broader context by exploring what shapes parents' decisions and behaviours around screen time for 3–4-year-olds.

The first step was to explore the existing evidence base through a systematic review that mapped what was known- and what remained unanswered- about screen time in the early years. It revealed a limited understanding of how different types of sedentary behaviour relate to both fine and gross motor development, specifically in 3–4-year-olds, a period of rapid skill growth. While sedentary behaviour was often studied in older children and adults, much less was known about its effects in children aged

3-4 years. Findings from this review highlighted potential links between high levels of sedentary behaviour and screen time, and poorer motor skill development. It was evident that more targeted research was needed to understand how these behaviours shape a child's development.

Guided by this insight, the second study turned to data analysis information from the SUNRISE International study- a large, culturally diverse sample of 3-4-year-olds. Findings from this study were striking- while most children met the restraint guideline (such as limits on being strapped into prams or seats for too long), adherence to screen time and overall sedentary behaviour guidelines was much lower. Just 42% met the sedentary behaviour guideline, and only 50% met the screen time guideline. Notably, the data showed that children who met these guidelines were more likely to be on track with both fine and gross motor skill development. These findings add new evidence to the emerging concern that excessive screen time and sedentary behaviour may be compromising key developmental milestones in 3–4-year-olds. These findings highlighted that despite the guideline recommendations, many young children exceed screen time guidelines, leaving a fragmented understanding of its true impact (O'Brien et al., 2018; Poitras et al., 2017). Unlike prior research, which often lacked cultural and socioeconomic diversity, this study utilised data comprising participants across multiple backgrounds, revealing patterns and associations that hold relevance beyond any single region or population.

Building on the findings from study 2, the final study shifted the lens from observation to understanding by listening to the voices of parents. Using both quantitative and qualitative methods, this study reached families of 3-4-year-olds across Scotland, spanning both high- and low-income settings. The analysis revealed that only around 40% of children met the screen time guideline, aligning with earlier studies (Galland et al., 2012; Ofcom, 2015, 2016; Okely et al., 2021; Chong et al., 2023) and evidence of screen time overuse. Behind these figures, however, lay everyday realities: parents who, while managing employment, caregiving, and domestic responsibilities, frequently relied on screen time as a pragmatic strategy to keep children occupied or calm. Parents described barriers to reducing screen time, including demanding work schedules, limited childcare support, and even weather conditions, all of which increased dependence on screen time for entertainment and daily routines. Some parents also acknowledged using screens to carve out brief moments of rest or self-care, highlighting the significant

pressures families face in trying to support children's development while managing day-to-day life. Yet they also suggest possible solutions: clearer public messaging, greater awareness of screen time guidelines, and supportive community- or policy-level initiatives could help them make healthier choices. By investigating these perceptions, this thesis provides a crucial qualitative dimension, uncovering the barriers parents face in managing screen time in a rapidly evolving technological world (Chong et al., 2023; Mallawaarachchi et al., 2022). This directly contributes to understanding the real-world complexities surrounding screen time beyond mere quantitative measurements.

This thesis bridges several important research gaps in the study of screen time and sedentary behaviour among children aged 3-4 years. Most notably, it addresses:

1) The lack of research specifically isolating the nuanced relationships between fine and gross motor skill development and screen/sedentary behaviours in the 3–4-year-old age group, as opposed to broader or mixed "preschool" categories that often combine children of very different developmental stages.
2) The scarcity of large-scale, culturally diverse samples in 3-4-year-olds; most prior work is based on high-income or homogenous populations, limiting generalisability to wider global settings. This thesis strengthens the evidence base by including children and parents from a range of socioeconomic and cultural backgrounds.
3) A limited understanding of parental and contextual factors- environmental, socioeconomic, and cultural- that shape screen time in 3–4-year-olds, especially as expressed by parents themselves. Previous studies have rarely integrated mixed methods to understand both the quantity of screen time and the real-life reasons behind it.
4) The need for a multi-layered ecological approach: Although some prior studies have examined multiple influences on children's screen time, relatively few have considered the combined roles of family, community, organisational, and policy factors. This thesis contributes to that body of work by drawing these spheres together and using them to inform more holistic, system-level recommendations.

5) Finally, this thesis starts to address the lack of population-specific adherence data for screen time and sedentary behaviour guidelines, especially for 3-4-year-olds in Scotland, adding regional evidence that can inform both policymakers and practitioners.

In summary, this thesis makes a unique contribution by focusing precisely on a critical developmental period (3–4-year-olds), ensuring relevance across diverse populations, incorporating parents' real-world perspectives, and advocating for comprehensive systems-level action—thus establishing a foundation for more targeted and effective interventions in young children's screen time and sedentary behaviours.

5.4. Implications of the Thesis

Previous studies have reported low adherence to the WHO sedentary behaviour guideline since its development. Findings from this thesis not only add to the existing evidence of low adherence to the sedentary behaviour guideline but also provide evidence of negative associations with motor competence (studies 1 & 2) and highlight factors that may be contributing to this low adherence in 3-4-year-olds (study 3). Understanding the implications of the findings of this thesis for practice and identifying areas for future research are critical for developing effective interventions. The implications of these findings for public health researchers and practitioners are therefore discussed below.

5.4.1 Implications for Practice

Promoting adherence to sedentary behaviour guidelines for children under five is crucial for ensuring healthy development (Draper et al., 2024). With findings from this thesis adding to the existing evidence of low adherence to the sedentary behaviour guideline, strategies to promote adherence are needed for public health professionals and policymakers. More effective strategies to promote adherence to the sedentary behaviour guideline should focus on parents, caregivers, and early childhood education settings, and highlight evidence of the adverse effects of excessive sedentary behaviour, such as delayed motor skill development.

Again, developing effective interventions to reduce high levels of sedentary behaviour among 3-4-year-olds is an important area for practice. This thesis provides components of barriers and facilitators to consider when developing interventions to limit screen time in children. Based on the experiences and

perceptions of parents of 3-4-year-olds shared in parts of this thesis, effective policies, public health programs, and community-based interventions may be developed to promote and encourage other movement behaviours (physical activity and sleep) while limiting sedentary behaviour in children. This may be in the form of policy and program developments that encourage childcare centres to balance learning with physical activity, ensuring that sedentary periods do not dominate the day. An example is the 'start active stay active' guideline, designed to promote physical activity and reduce sedentary behaviour, and to provide guidelines for parents, caregivers, and other professionals working with children (Chief Medical Officers, UK, 2011/2016). Also, raising awareness of the WHO Guidance for Early Childhood Education and Care Settings (WHO, 2019) and the impact of excessive sedentary behaviour may encourage parents and caregivers to set screen time limits, engage children in active play, and use family-friendly activities to promote movement.

With regards to dissemination, there is increasing recognition that parents of young children frequently access information through digital and social media platforms. Research has shown that some parents rely on online communities and social media for parenting advice and health-related information, highlighting the potential of these platforms as channels for disseminating child health guidelines and intervention strategies (Lupton et al., 2016; Mertens et al., 2024; de Pablo et al., 2025; Phillipson, 2025). Social media use is widespread in the UK, with over 80% of the population engaging with at least one platform and adults commonly using multiple platforms daily (DataReportal, 2024; Sprout Social, 2025). Platforms such as Facebook and Instagram have particularly large user bases among adults, while TikTok continues to grow rapidly across age groups, including older demographics (Sprout Social, 2025; Calloway, 2026). Therefore, communicating the existence of the screen time guidelines through these commonly used social media channels may provide an effective way of reaching parents and caregivers. Engaging with parents through these online portals may improve awareness of the WHO screen time guideline, and also educate parents of the negative impact excessive screen time may have of their children's health and development.

Findings of this research may be relevant to groups involved in supporting the health and development of young children. First, parents and caregivers represent key end users, as they play an important role in shaping children's daily routines, and also have influence in their movement behaviour including sedentary behaviour. The insights from this study may help parents better understand how sedentary behaviour negatively impacts children's motor competence and encourage a more balanced daily activity patterns. Second, early childhood educators and childcare providers may use these findings to inform the design of daily schedules and provide environments that promote active play and limit prolonged sedentary behaviour within early learning settings (WHO, 2017). Third, public health practitioners and health promotion professionals can use the findings when developing interventions and community-based programmes aimed at supporting healthy movement behaviours during the early years. Finally, policymakers and guideline developers may find the results useful in refining and disseminating movement behaviour guidelines for young children, particularly in identifying practical barriers families face in adhering to screen time recommendations (WHO, 2017; DeCraemer et al., 2024). Together, these groups represent important stakeholders who can translate the research findings into strategies that support healthier movement behaviours and developmental outcomes in early childhood.

5.4.2 Implication for Future Research

Although findings from this thesis show a predominantly negative association between excessive screen time and motor competence, with parents of 3-4-year-olds highlighting other negative impacts of excessive screen time on their children's health and development, more research is required to differentiate the effects of various sedentary behaviours. Although excessive sedentary behaviour is often associated with negative health outcomes, certain types of sedentary activities, such as educational screen time (interactive learning applications and e-books), can enhance cognitive skills, literacy, and problem-solving abilities in children (Kirkorian et al., 2016). Other sedentary activities, such as reading, drawing, and puzzle-solving, and some forms of digital engagement, such as participating in virtual educational programs, can foster academic growth and engagement and encourage creativity, concentration, and critical thinking skills in children. (Rideout et al., 2017). A systematic review by

Mallawaarachchi et al. (2024), which explored early childhood screen time context and cognitive and psychological outcomes, reported that co-use of screen time was positively associated with cognitive outcomes (Mallawaarachchi et al., 2024). Future research should, therefore, explore how different types of sedentary activities (e.g., passive screen time vs. interactive learning) affect different health outcomes in children. This could be in the form of researchers adopting a more robust study design (longitudinal/cohort studies, RCTs), and capturing the 'type' of sedentary behaviour (differentiating between the context, content and interaction), using developmentally appropriate outcome measures (validated, age-appropriate tools to assess specific outcomes) or population consideration (inclusion of individuals with developmental delays/disabilities)

As noted previously, screen type, content, and context all matter to health in addition to screen time. Emerging evidence suggests that the impact of screen time on child development may vary depending on the nature, content, and context of screen use. For example, passive screen viewing, such as watching television or videos, has often been associated with negative developmental and behavioural outcomes, whereas more interactive forms of screen engagement, such as educational apps or co-viewing with parents, may support aspects of cognitive and language development (Radesky et al., 2016; Madigan et al., 2019). Similarly, some sedentary behaviours that involve cognitive engagement, such as reading or structured learning activities, have been linked with positive developmental outcomes despite being classified as sedentary (Carson et al., 2016). The present study did not differentiate between passive and interactive forms of screen use, as the available measures captured overall screen time exposure. As such, the findings should be interpreted with caution, as they may mask important differences in how various types of screen time relate to motor competence. Future research may therefore benefit from more detailed measurement approaches that distinguish between screen content, context of use, and level of child engagement in order to better understand the complex relationship between sedentary behaviour and child motor competence.

With the rapid expansion of digitalisation and the proliferation of technological devices in recent years, future research should delve deeper into how these digital tools can be effectively utilised to limit sedentary behaviour. Until recently, screen time research primarily focused on traditional media such as TV or DVDs. However, with the rapid rise in ownership and use of mobile devices, alongside the

increasing variety of content specifically designed for young children, the nature of screen time has changed dramatically. This shift has important implications for how much and what types of screen time children engage in today, how screen time should be accurately measured, and how societal norms around screen time are evolving. Recognising these changes is crucial for developing relevant guidelines and research methods that reflect the current digital landscape. This may involve exploring innovative strategies that not only promote physical movement and exercise but also help mitigate excessive screen time among 3-4-year-olds. For example, using exergaming (exercise + gaming) and activity-promoting apps that integrate movement into screen time may increase caloric expenditure, heart rate, and coordination, and improve overall health outcomes in early years (Staiano, 2011).

Future research exploring the perceptions of other stakeholders at different levels of the socio-ecological model could offer deeper insights into children's screen time. Policy researchers should examine how government regulations and policies, educational curricula, and technological advancements shape sedentary behaviour in children. This approach may be beneficial when designing interventions and programs targeted at limiting excessive sedentary behaviour to ensure parents are aware of both the risks and benefits associated with screen time.

Future studies should employ stronger study designs (e.g., longitudinal and controlled intervention studies) with larger sample sizes to better understand the health and developmental risks associated with excessive screen time and sedentary behaviour. Again, future research should aim to develop a well-established, validated, and reliable tool for objectively assessing screen time and screen content/type. This may help provide more accurate, reproducible quantitative data, distinguish between types and contexts of screen time, and support nuanced analysis, such as whether interactive media is more beneficial than passive video watching. Measuring tools such as inclinometers, which capture postures more accurately than hip-worn accelerometers and have been used and validated in children, may be used in assessing sedentary behaviour in the early years (Mwase-Vuma et al., 2022; Davies et al., 2012).

The ASQ-3, used in this thesis to measure motor competence, is a practical, valid, and widely used parent-report screening tool that assesses broad developmental domains, including gross and fine motor skills in 3-4-year-olds. However, it relies on subjective parental reporting and provides a less detailed, less objective assessment than performance-based tools. The Test of Gross Motor Development-2 (TGMD-2) often considered a 'gold standard' for gross motor skills, provides a standardised evaluation of fundamental gross motor abilities but does not capture fine motor skills or balance comprehensively. While there may be no single tool that assesses all aspects of motor competence in 3- to 4-year-olds, combining parent-reported measures (such as the ASQ-3) and performance-based tools (such as the TGMD-2) would provide a more comprehensive assessment.

5.4.3 Practical Rationale: Feasibility and Methodological Depth

While the integrated 24-hour movement behaviour paradigm- which encompasses physical activity, sedentary behaviour, and sleep- described in the introduction chapter of this thesis emphasises the interconnected nature of these behaviours, this thesis has chosen to focus on sedentary behaviour for practical reasons. An integrated examination of all 24-hour movement behaviours may be desirable in theory, several practical and feasibility-related constraints influenced the scope and design of this thesis. Conducting research with 3–4-year-olds presents its unique challenges, particularly in accessing early years settings and collecting objective and developmental data within limited timeframes. For example, the inclusion of motor skill assessments in study 2 required direct access to nursery and early child centre settings as well as sufficient time to administer the standardised assessments to the children. This may have proved challenging particularly in the post-COVID-19 period, where access to nurseries was restricted, external visitors were limited, and time available for the assessment may have reduced due to competing educational and safeguarding priorities.

Recruitment of participants for study 3 also presented its own challenges. Engaging parents of children 3-4 year olds required navigating time constraints, competing responsibilities, and varying levels of interest in research participation. Hence, collecting comprehensive data across all movement behaviours (physical activity, sedentary behaviour, and sleep), alongside motor skill assessments and parental

perspectives, would have substantially increased participant burden and may have negatively impacted recruitment, retention, and data quality.

Given these practical considerations, a focused approach on sedentary behaviour was adopted to ensure methodological depth and feasibility. Prioritising sedentary behaviour—particularly screen time—allowed for a more robust and in-depth investigation, using a detailed systematic review, secondary data analysis, and complementary quantitative and qualitative mixed method approach. This enabled a deeper exploration of both behavioural associations with (motor competence), and contextual influences (parental perspectives), while remaining sensitive to the constraints of working with children 3-4 year olds and their families.

Therefore, rather than being a limitation, the focused design of this thesis reflects a practical decision based on what was realistically achievable. It was important to balance what could be done within the study with the time demands on parents and children, while still collecting meaningful and detailed data. By focusing specifically on sedentary behaviour, this thesis was able to explore the topic in more depth and provide useful insights into an area that is still not well understood within the wider 24-hour movement behaviour framework.

5.5 Strengths and Limitations of the Thesis

It is important to acknowledge overarching strengths and limitations across the entire thesis, while specific strengths and limitations for each study are discussed in the individual thesis chapters. Some overall strengths and limitations identified in the thesis are included below.

5.5.1 Strengths

To the best of our knowledge, this is the first study of its kind to provide a report on the levels of meeting the screen time guideline in children aged 3-4 years old in Scotland, making the results of this thesis

novel. The primary data collection in this process also adds to the existing database of movement behaviours and may serve as a baseline for future research.

The use of a relatively large sample, compared with the previous literature, from the SUNRISE international database, makes it more likely that the findings of this thesis apply to a broader population rather than being limited to a specific region or demographic group.

While it should be acknowledged that focusing solely on 3-4 year olds may be seen as a limitation, there are also advantages to this approach. By focusing solely on the 3–4-year-old age group and narrowing the scope to specific exposures (screen time and sedentary behaviour) and an outcome (motor competence), the research gains clarity and precision. This targeted approach allows for more meaningful interpretation of findings, as it avoids the variability and generalisations that often arise in broader studies. As a result, the evidence produced in this thesis is likely to be more relevant, applicable, and actionable for informing interventions for 3-4-year-olds.

The use of device-based measurement tools, including the activPAL, for assessing sedentary behaviour in 3-4-year-olds ensures accurate and effective tracking of sedentary behaviour in this age group, as these tools have been validated and considered reliable in this age group. Similarly, using a validated and reliable tool (ASQ-3) to assess motor skills in 3-4-year-olds, as shown in this thesis, provides a standardised measure of motor skill development in this age group.

Overall, this thesis combined multiple research approaches- a systematic review, secondary data analysis, quantitative and qualitative mixed method studies- which strengthen the study's validity, depth, and comprehensiveness. The first study, which was a systematic review, established a strong theoretical foundation by providing a clear understanding of what was known in the area of sedentary behaviour in 3-4-year-olds, highlighting the research gaps. The use of secondary data collection in the second study also allowed authors access to large-scale and more geographically representative data samples (that could not have been easily collected within this research period) to broaden the scope of analysis. Finally, using the quantitative and qualitative mixed method approach enhanced a comprehensive analysis, with the quantitative study providing estimates of the prevalence of meeting the screen time guideline in Scotland, while the qualitative study provided in-depth contextual understanding of the factors which might explain low levels of adherence.

The ARC method utilised in the quantitative part of the thesis allowed participants to join discussions from home at their convenience, eliminating travel time. This method also fostered interactive conversations, as participants could share and build on each other's insights, which may not have happened in individual interviews.

5.5.2 Limitations

Overall, the focus of this thesis on sedentary behaviour may overshadow the importance of promoting other movement behaviours, such as active play and structured movement, which are crucial for children's overall development. However, the focus on sedentary behaviour in this thesis was, as explained above, based on scientific and practical reasons, with research (Leppanen et al., 2019; De Craemer et al., 2022) highlighting low adherence to the sedentary behaviour guideline as a significant explanation for low adherence to the overall movement guidelines. With studies showing that the ideal combination of physical activity, sleep and screen time may provide health and developmental benefits in early years, examining only sedentary behaviour may provide an incomplete picture of children's overall movement patterns, as it limits the interplay between different types of activity. Again, focusing solely on sedentary behaviour in a study may inadvertently stigmatise certain sedentary activities, such as reading or creative play, without recognising their potential educational benefits.

The use of non-validated parent-report measures used to assess screen time across all studies in this thesis may have been biased and prone to under- or over-reporting, as well as potentially unstable estimates of children's screen time. A review by Byrne, Terranova, and Trost (2021) noted that no gold standard or objective method- such as passive digital tracking or observational protocols- currently exists for measuring screen time in young children. This methodological gap raises concerns about accuracy, comparability, and bias. Although the lack of robust measurement tools may limit the precision of findings in this thesis, the questionnaire used for screen time measurement in this thesis was developed with the SUNRISE international questionnaire and can be practical and culturally appropriate for the corresponding age group.

Due to the small sample size used in study 3 of this thesis, the generalisability and applicability of the findings of this study to other settings may be limited. Again, the issue of sample size in study 3 may

have influenced the statistical power. Future studies with a larger, more diverse sample in the target population may increase the statistical power of the findings, provide a more precise estimate, and enhance their generalizability within the target population.

Another limitation relates to the use of a convenience sampling approach in the qualitative part of the study which may not be a representative of the entire 3-4-year-old population in Scotland. Participants were recruited from those who had already taken part in the quantitative part of the study and expressed willingness to engage in the qualitative phase. While this approach may limit the generalisability of findings to the wider 3-4 year old population, it provided an important advantage by enabling deeper exploration of perspectives from parents within the same participant group whose quantitative data had already been collected, strengthening the mixed-methods study design. In addition, the themes identified across the discussion groups were consistent across participants and began to show signs of thematic saturation, suggesting that the key issues surrounding screen time and guideline adherence among parents of 3–4-year-olds were adequately captured within the sample.

A further limitation relates to the use of only one valid day of activPAL data for inclusion in the analysis. Although the activPAL provides an objective and valid measure of sedentary behaviour and posture, and the inclusion criterion of at least one day wear period was applied to maximise sample retention and maintain statistical power, a single day of monitoring may not fully capture and reflect children's habitual sedentary behaviour. Sedentary behaviours in children can vary substantially from day to day due to factors such as childcare attendance or family routines. Previous research suggests that multiple days of monitoring, typically between 3-7 days, are recommended to provide a more reliable estimate of habitual sedentary behaviour in children (Davies et al., 2012a; Hislop et al., 2014). Consequently, the use of a single day of data in this present study may increase the likelihood that the sedentary behaviour measure may not be a true reflection for some participants. Future studies should therefore aim to include multiple monitoring days, including weekends to better capture habitual sedentary behaviour and strengthen the reliability of estimates of sedentary behaviour in 3-4 year olds.

5.6 Conclusions

This thesis has explored the relationship between sedentary behaviour/screen time and health outcomes, with a particular focus on motor competence in 3-4-year-olds. Using a combination of systematic review, secondary data analysis, and qualitative investigation, this thesis provides a well-rounded examination of how screen time may influence motor competence in 3-4-year-olds and highlights the role of parental perceptions in shaping children's screen time.

Findings from this thesis confirm that screen time is a prevalent behaviour among 3-4 year olds, with excessive screen time patterns identified across multiple datasets in this thesis. The systematic review revealed growing evidence that excessive sedentary behaviour, particularly screen-based sedentary behaviour, may be associated with lower motor competence in 3-4-year-olds. Although causality remains difficult to establish due to methodological limitations in the included studies, the consistency of associations between high levels of sedentary behaviour and reduced motor competence is concerning and warrants attention.

The secondary data analysis study in this thesis further reinforced this concern. A high proportion of 3-4-year-olds reported low adherence to the screen time guideline, with those who accumulated higher sedentary behaviour at greater risk of delays in fine and gross motor skill development.

Additionally, the qualitative exploration of parental perceptions shed light on the lived realities of managing screen time in 3- to 4-year-olds. Parents reported a range of barriers to meeting screen time recommendations, including health barriers, time pressures and busy schedules, weather and season barriers, and personal parental barriers. At the same time, facilitators such as knowledge of the screen time guideline and family structures were identified as potential enablers for limiting screen time and meeting the screen time guideline.

Taken together, the findings of this thesis highlight the importance of adherence to the WHO screen time guideline, while also recognising the factors that shape 3-4-year-olds' sedentary behaviour. They also underscore the need for education on the detriments of excessive screen time as well as the dissemination of the WHO screen time guideline.

It is recommended that future research aim to develop a valid, more reliable approach for assessing screen time in children and examine associations using different study designs, such as longitudinal or

experimental studies, to track outcomes over time. Finally, interventions to reduce screen time in 3-4-year-olds may be coupled with initiatives that promote physical activity and play, and also engage parents as central agents of change in the early years. Ultimately, this thesis contributes to the growing body of evidence calling for a more nuanced, evidence-based approach to managing screen time for 3-4-year-olds to support motor competence and overall health and development.

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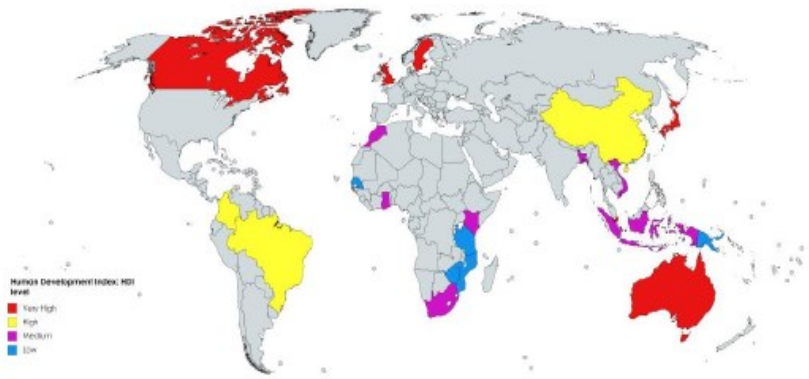
Thesis Appendix

Appendix 1: Parent Questionnaire used for the SUNRISE international study.

PARENT/GUARDIAN QUESTIONNAIRE

INTERNATIONAL SURVEILLANCE STUDY OF 24-HOUR MOVEMENT BEHAVIOURS IN THE EARLY YEARS: The SUNRISE Study



Instructions: This questionnaire is for parents/guardians who have a child approximately aged 4 years old (48-59 months old). Please take your time and read each question carefully. Choose the answer that best describes you and your child by placing a checkmark (√) in the box provided or writing in the space provided. If there is a question that you do not want to answer, you do not have to. Your responses will be kept confidential.

CHILD PARTICIPANT IDENTIFICATION INFORMATION			
1.	Name of the Elementary School or Childcare Centre:		
	.....		
2.	Parent/Guardian's relationship to the child participating in the study:		
	☐ Mother ☐ Father ☐ Grandmother ☐ Grandfather ☐ Legal Guardian ☐ Other (please specify):		
MODULE OF CHILD AND PARENT/GUARDIAN BACKGROUND			
3.	What is the date of birth of the child? (dd/mm/yyyy)	4.	If the child's date of birth is not known, how old is the child in years? (Age in completed year)
	...../...../.....		.....years old
5.	What is the sex of the child?		
	☐ Boy ☐ Girl		
6.	What is the gender of the main caregiver?	7.	What is your age in years?
	☐ Man ☐ Woman ☐ Other (please describe: .....)		.....years old
8.	What is the highest level of parental/guardian education completed by a member of your household?		
	☐ No formal schooling ☐ Primary school ☐ Secondary or high school ☐ Post-secondary education ☐ Don't know/refused		
9.	Is your child (Mark more than one circle to specify, if applicable):		
	☐ Aboriginal person ☐ White ☐ South Asian (e.g., East Indian, Pakistani, Sri Lankan, etc.) ☐ Chinese ☐ Black ☐ Filipino ☐ Latin American ☐ Arab ☐ Southeast Asian (e.g., Vietnamese, Cambodian, Laotian, Thai, etc.) ☐ West Asian (e.g., Iranian, Afghan, etc.) ☐ Korean ☐ Japanese ☐ Other (please specify): ..... ☐ Don't Know/refused		

QUALITY CONTROL Staff initials:_____ Date:____/____/____
DATA ENTRY Staff initials:_____ Date:____/____/____

CORE: PHYSICAL ACTIVITY, SCREEN TIME, SEDENTARY BEHAVIOUR, AND SLEEP			
The next questions ask about your child's movement behaviours. Please report the number of hours and minutes per day (for all the questions). E.g. 1 hour and 30 mins			
10.	In a 24 hour period **in the past week**, how much time did the 3-5 year old child who is participating in this study spend on:		
10a.	In a variety of physical activities, spread throughout the day? Physical activity includes active movements, such as going for a walk, skating, running around, playing at a spray park or pool, riding a tricycle, gymnastics, dancing, playing at the park, playground, or in the yard.		.....hours .....minutes
10b.	In energetic play that causes him/her to 'huff and puff' and increases his/her heart rate (this would be part of the total time spent in a variety of activities just mentioned).		.....hours .....minutes
10c.	Using any electronic screen device such as a smart phone, tablet, video game, or watch television or movies, videos on the internet while they were sitting or lying down?		.....hours .....minutes
11.	**In the past week**, were there any days where your child who is participating in this study:		
11a.	Was restrained for more than one hour at a time in a stroller, car seat, or a high chair/booster seat?	**11b.**	Sat for more than 30 minutes at a time?
	☐ Yes ☐ No		☐ Yes ☐ No
12.	How many hours of sleep does this child get in a typical 24-hours day (including naps)?		.....hours .....minutes
13.	Does the child use electronic screen devices (e.g. TV, video game, computer, tablet or smartphone) in the 2 hours before bedtime on a daily basis?		
	☐ Yes ☐ No ☐ Don't know		
14.	**If Yes**, how close to bedtime does the child usually use these devices? **If no, go to question 23.**		
	☐ Closer than 30 minutes before bedtime ☐ 30 minutes to less than 1 hour before bedtime ☐ Between 1 and 2 hours before bedtime		
15.	Does the child have electronic screen devices in the room where he/she sleeps (e.g. TV, video game, computer, tablet or smartphone)?		
	☐ Yes ☐ No		

QUALITY CONTROL Staff initials:_____ Date:____/____/____
DATA ENTRY Staff initials:_____ Date:____/____/____

16.	On a 24 hours period in the past week, how much total time did the 3-5 year old child who is participating in this study spend sitting?		.....hours .....minutes
17.	How often do you use an electronic media device to educate this child?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
18.	How often do you use an electronic media device to calm down this child when he/she is upset?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
19.	How often do you use an electronic screen device to keep this child busy while you get things done?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
20.	How often do you use a smartphone to make calls, text messages, check email, watch a video during meals with the child?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
21.	How often do you use a smartphone to make calls, text messages, check email, watch a video during playtime with the child?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
22.	How often do you use a smartphone to make calls, text messages, check email, watch a video during bedtime routine with the child?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
23.	How often do you use a smartphone to make calls, text messages, check email, watch a video during travel time with the child?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
24.	How often do you use a smartphone to make calls, text messages, check email, watch a video while going for walks with the child?		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		
25.	Does the child have a consistent bedtime?	**26.**	Does this child have a consistent wake-up time?
	☐ Yes, bedtime does not vary by more than 30 minutes each day ☐ No, bedtime can vary more than 30 minutes each day		☐ Yes, wake-up time does not vary by more than 30 minutes each day ☐ No, wake-up time can vary more than 30 minutes each day
27.	How often is there a bedtime routine for this child (e.g., bath time, saying goodnight, storytelling, etc.)		
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know		

QUALITY CONTROL Staff initials:_____ Date:____/____/____
DATA ENTRY Staff initials:_____ Date:____/____/____

28	During the past week, how many days did you or other household members read to this child?	
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Don't know	
29.	On a scale of 1 to 7, with the higher number indicating higher quality, how would you rate the quality of this child's sleep? 1 would indicate very difficult to settle, wakes many times during the night for prolonged periods and is very restless (tosses and turns, throws off bedclothes) while 7 would indicate settles and drifts off to sleep within a few minutes, sleeps right through the night, and has a very sound, deep sleep)	
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7	
30.	Over a typical weekday, how much time does the child spend as a passenger in a motor vehicle (e.g. a car, bus, motorcycle)	.....hours .....minutes
31.	Over a typical weekend day, how much time does this child spend as a passenger in a motor vehicle (e.g., a car, bus, motorcycle)	.....hours .....minutes
32.	How often does this child watch a screen when you are in transit (e.g., car, public transit, or stroller)?	
	☐ Not Applicable (i.e., I do not have screen devices) ☐ Never ☐ Sometimes ☐ Often ☐ Don't know	
33.	On a typical weekday, how much time does your child spend outside?	
	☐ Less than one hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 hours ☐ 6 hours or more ☐ Don't know	
34.	On a typical weekend day, how much time does your child spend outside?	
	☐ Less than one hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 hours ☐ 6 hours or more ☐ Don't know	
35.	Comments:	
36.	Date of the survey completed (dd/mm/yyyy):	...../...../.....

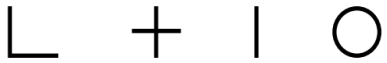
This is the end of the questionnaire. Thank you very much for your participation!

Please return the questionnaire in the sealed envelope to the educator at your child's school or daycare centre.

QUALITY CONTROL Staff initials:_____ Date:____/____/____
DATA ENTRY Staff initials:_____ Date:____/____/____

Appendix 2: Fine and gross motor skill tasks used for the SUNRISE International study.

FINE MOTOR

	YES	SOMETIMES	NOT YET	
1. Does your child put together a five- to seven-piece interlocking puzzle? *(If one is not available, take a full-page picture from a magazine or catalog and cut it into six pieces. Does your child put it back together correctly?)*	○	○	○	___
2. Using child-safe scissors, does your child cut a paper in half on a more or less straight line, making the blades go up and down? *(Carefully watch your child's use of scissors for safety reasons.)*	○	○	○	___
3. Using the shapes below to look at, does your child copy at least three shapes onto a large piece of paper using a pencil, crayon, or pen, without tracing? *(Your child's drawings should look similar to the design of the shapes below, but they may be different in size.)* 	○	○	○	___
4. Does your child unbutton one or more buttons? *(Your child may use his own clothing or a doll's clothing.)*	○	○	○	___
5. Does your child draw pictures of people that have at least three of the following features: head, eyes, nose, mouth, neck, hair, trunk, arms, hands, legs, or feet?	○	○	○	___
6. Does your child color mostly within the lines in a coloring book or within the lines of a 2-inch circle that you draw? *(Your child should not go more than 1/4 inch outside the lines on most of the picture.)*	○	○	○	___
		FINE MOTOR TOTAL		___

GROSS MOTOR

	YES	SOMETIMES	NOT YET	
1. Does your child catch a large ball with both hands? *(You should stand about 5 feet away and give your child two or three tries before you mark the answer.)*	○	○	○	___
2. Does your child climb the rungs of a ladder of a playground slide and slide down without help?	○	○	○	___
3. While standing, does your child throw a ball *overhand* in the direction of a person standing at least 6 feet away? To throw overhand, your child must raise his arm to shoulder height and throw the ball forward. *(Dropping the ball or throwing the ball underhand should be scored as "not yet.")*	○	○	○	___
4. Does your child hop up and down on either the right or left foot at least one time without losing her balance or falling?	○	○	○	___
5. Does your child jump forward a distance of 20 inches from a standing position, starting with his feet together?	○	○	○	___
6. Without holding onto anything, does your child stand on one foot for at least 5 seconds without losing her balance and putting her foot down? *(You may give your child two or three tries before you mark the answer.)*	○	○	○	___
		GROSS MOTOR TOTAL		___

Appendix 3: Questionnaire used for Study 3- Mixed Method Study

Item 1: Contact Information

1. What is your first and last name?
    i. (Open Text)

2. What is your email address?
    i. (Open Text)

3. What is the first line of your home address?
    i. (Open Text)

4. What is your postcode?
    i. (Open text)

Item 2: Interest in related study

1. "Would you be interested in participating in additional research to help us understand your perceptions of physical activity, screen time and sleep and the barriers and facilitators you experience when trying to enable your child to be active, obtain a good night's sleep and limit their screen time."
    - ❑ Yes
    - ❑ No

Item 3: Child and parent demographics

1. What is your date of birth?
    i. (dd/mm/yyyy)

2. What is your gender?
    - ❑ Male
    - ❑ Female
    - ❑ Other (Please specify)

3. What is your ethnic group?
    - ❑ White
    - ❑ Asian
    - ❑ Asian Scottish
    - ❑ Asian British
    - ❑ African
    - ❑ Caribbean or Black
    - ❑ Mixed or multiple ethnic groups
    - ❑ Other ethnic group (Please specify)

4. What is your relationship to the child participating in the study?

- ❑ Mother
- ❑ Father
- ❑ Grandmother
- ❑ Grandfather
- ❑ Legal Guardian
- ❑ Other (Please specify)

5. What is the highest level of parental/caregiver education completed by a member of your household?

   - ❑ No formal schooling
   - ❑ Primary school
   - ❑ Secondary school standards/ intermediates/ nationals
   - ❑ NVQs
   - ❑ No formal qualifications
   - ❑ Scottish Highers
   - ❑ Advanced Highers or 6th year studies
   - ❑ Degree (or degree level qualification)
   - ❑ Not yet finished education
   - ❑ Don't know/ rather not answer

6. What is the date of birth of your child?
   i. (dd/mm/yyyy)

7. What is the sex of your child?
   - ❑ Male
   - ❑ Female
   - ❑ Other (Please specify)

Item 4: Movement behaviours

The next questions ask about your child's movement behaviours.

Please report the number of hours and minutes per day (for all the questions). E.g. 1 hour and 30 mins

1. On a 24-hour period **in the past 5 days**, how much time did the 3-4-year-old child who is participating in this study spend: Please record this as accurately as you can to the nearest minute

a) In a variety of physical activities, spread throughout the day? For example: active play, running, playing with balls, moving to music/dancing, swimming, riding a scooter/tricycle/bike
   i. Hours and minutes

b) In energetic play that causes him/her to 'huff and puff' and increases his/her heart rate (this would be part of the total time spent in a variety of activities as reported in the previous question).

i. Hours and minutes

c) Using any electronic screen device such as a smart phone, tablet, video game, or watch television or movies, videos on the internet while they were sitting or lying down?
   i. Hours and minutes

2. In the past 5 days, on days that you spent with your child (i.e., they did not go to childcare/preschool, and you were not at work), were there any days where the 3-4-year-old child who is participating in this study:

a) Was restrained for more than one hour at a time in a stroller, car seat, or on back or a scooter/moped?
   ❑ Yes
   ❑ No

b) Sat for more than 30 mins at a time?
   ❑ Yes
   ❑ No

3. How many hours of sleep does this child get in a typical 24-hours day (including naps)?
   i. Hours and minutes

4. Does the child have a consistent bedtime?
   ❑ Yes, bedtime does not vary by more than 30 minutes each day
   ❑ No, bedtime can vary more than 30 minutes each day

5. Does the child have a consistent wake-up time?
   ❑ Yes, wake-up time does not vary by more than 30 minutes each day
   ❑ No, wake-up time can vary more than 30 minutes each day

6. Does your child nap?
   ❑ Yes
   ❑ No

7. If yes, for how long does your child nap?
   i. Hours and minutes

8. Does the child use electronic screen devices (e.g. TV, video game, computer, tablet or smartphone) in the 2 hours before bedtime on a daily basis?
   ❑ Yes
   ❑ No

9. If yes, how close to bedtime does the child usually use these devices?
   ❑ Closer than 30 minutes before bedtime
   ❑ 30 minutes to less than 1 hour before bedtime
   ❑ Between 1 and 2 hours before bedtime

Note: Once questionnaire is completed message reads, "Thank you for completing our questionnaire. A researcher will be in contact with you soon for the next stages of research."

Appendix 4: Screening questions used for Study 3- Mixed Method Study

1. Do you have a child aged 3-4 years?
   - ❑ Yes
   - ❑ No

2. Do you live in Scotland?
   - ❑ Yes
   - ❑ No

3. Is your household income
   - ❑ Less then £16,000 per year (£1,333 per month)
   - ❑ between £16,000 and £25,000 per ear (£1,333 and 2,083 per month)
   - ❑ more than £25,000 per year (£2,083 per month)

Appendix 5- Parent Barriers and Facilitators to Building Better Days

Welcome and Topic Overview (post 1)

Hello everyone and welcome to this Facebook group. My name is XXXX, I am a research assistant at the University of Strathclyde, and I will be acting as the facilitator in this Facebook page for the next 6 weeks. You are all here after taking part in an online survey and after your child wore an activity monitor. Hopefully this activity has given you some insight into what we will be discussing in this Facebook group. We will be talking about 24-hour movement behaviours. These are all the movement behaviours your child might take part in during the entire 24-hour period. For example, physical activity, screen time and sleep. Over the course of the 6 weeks, I will be posting two activities or questions per week, and we ask you to reply to these.

Ground Rules

Throughout our discussion be aware there are no right or wrong answers, only different points of view. Please feel free to share your point of view even if it is different from the rest of the group. You can share both positive and negative points of view.

Your comments and replies will be copied into a transcript. In this group we will all be able to see your names, but we will not use any names in our report. You can be assured of complete confidentiality. Please do not share any information discussed here outside of this group. This includes not talking to others about what is discussed in this group or taking screenshots of any of the comments or posts.

Before I introduce the first activity, I want to highlight some ground rules.

1. The Facebook group will discuss questions related to the topic of 24-hour movement behaviours.

2. Participants are expected to reply to the questions posted by the facilitator. There may be times when you do not want to reply or have anything to say about a topic but please try to respond to as many as possible.

3. Participants are expected and encouraged to express their opinion or give comments in the form of written text.

4. When replying directly to another participant's comments, please insert the person's name so that he or she will get notification of your response.

5. If you want to reply to a comment privately you can do so by messaging me directly.

6. Participants should not use foul language or post irrelevant photos or videos.

7. Once all participants have completed an activity or discussed a question posted by the facilitator, the facilitator will post another question. No more than two activities or questions will be posted in one week.

Last, I like to remind you that at any point in time you can withdraw from the study. If you wish to do so, please contact me directly.

Week 1: Introductions and Current Reflections

- My name is XXXX and I am father to 3 girls. During my time as a parent, I have been keen to see my children grow up with happiness and confidence. I know that a healthy lifestyle can help with these characteristics and hope I can learn something more from this study. Please tell me about you and your child.
- Starting and keeping a healthy lifestyle for you and your child includes being physically active, reducing the time during the day and night using screens, and getting a good night's sleep. What do you think of each of these 3 areas (i.e., being active, screen time use, and sleep) and do you think they are all just as important as each other? Please remember there is no right or wrong answer – this is all about your experiences and thoughts.

Week 2: Unique Activity Profile

- The recommended targets for your child's 24-hour movement behaviours include each of the following:
    - 3-hours being active per day with one of those hours being very active (i.e., out of breath),

    - A maximum of 1-hour using screens each day (this includes daytime and evening time use),
    - 10 to 13-hours sleep each day (this includes daytime napping and night-time sleep).
- Tell me what you think of these 3 recommendations, for example, did you know about them before this study, do you think they are achievable? What do you think are the benefits for your child if they can achieve each of these recommendations.
- By now you will have received your child's unique activity profile. I would love to hear what you found useful or interesting about your child's profile but also if there were any recommendations you would like to make about the profile (i.e., how does it look, is it easy to understand etc.). Your thoughts on this will help greatly in this study.
- Please look again at your child's unique activity profile and tell us how useful it is now that we have discussed the 3 recommendations. For example, do you think your unique activity profile will help you and your child develop healthier lifestyles, perhaps it makes you think differently about you and your child's 24-hour movement behaviours (physical activity, screen use, and sleep).
- Please remember the ground rules when posting your comments.

Week 3: What help have you had to help with your child's 24-hour movement behaviours?

- Week 3 has arrived as we reach the halfway stage! Once again, your participation is extremely useful and such an important part of this study. Thank you! Yet, please remember that you still have the right to withdraw from the study at any time you choose.
- This week I would really like to understand what helps you with your child's current 24-hour movement behaviours (being active, screen use, sleep). Remember there are no expectations and no wrong answers, I simply ask for your thoughts and experiences. For example, it may be that your local area provides lots of advice from the community (i.e., your local GP, your child's nursery or childcare service, and advertising), or perhaps you have been chatting about these things with your family and/or friends, you may live close to a play park making it easier

to be active or anything else you feel that has helped you and your child to be active, limit screen use, and/or sleep well.

- Having learned about the 3 recommendations last week, and receiving your child's unique activity profile, what changes have you tried to or plan to make to your child's 24-hour movement behaviours (for example, you may have tried to increase activity time, altered sleeping routines or habits, perhaps you've played more together with toys that did not involve a screen). Remember there are no expectations and no wrong answers, I simply want to learn from your thoughts and experiences.
- When considering the 3 elements (being active, screen time use, and sleep) do you think that each of these links with one another? Tell me why you think that?
- Please remember the ground rules when posting your comments.

Week 4: What difficulties do/have you faced?

- This week I would really like to understand what difficulties (i.e., barriers) you have experienced regarding your child's 24-hour movement behaviours (being active, screen use, sleep). Your responses will truly help me to understand how I can support families in the future. You could take some pictures and post these with a brief explanation (that would be amazing!) or you could simply text your thoughts onto our discussion group – whatever works best for you.
- Please remember the ground rules when posting your comments.

Week 5: Experiences and Thoughts

- Having learned about the 3 recommendations, and receiving your child's unique activity profile, have you tried to or are you planning to make any changes to your child's 24-hour movement behaviours (for example, you may have tried to increase activity time, altered

sleeping routines or habits, perhaps you've played more together with toys that did not involve a screen). Remember there are no expectations and no wrong answers so if you are not planning to make changes that is okay too. I simply want to learn from your thoughts and experiences.

- I would love to hear from you about who and what you think would help you and your child build a better day and live a healthier lifestyle based on the 3 recommendations (i.e., being active, reducing screen use, and good sleep). All your suggestions would be so warmly received and would allow us to make realistic differences for other families in the future.
- Please remember the ground rules when posting your comments.

Week 6: Almost there!

- This is our final week together . I would like you to share your experiences and thoughts in being part of this study. Again, there are no wrong answers as this is about your personal and unique experience. You may choose to include if you found the study helpful in making changes to you and your child's 24-hour movement behaviours or if perhaps you have found it has placed more pressure on you and your child. All experiences and thoughts would be greatly welcomed.
- We have reached the end of our learning journey together – thank you so much for your support and insights over these last 6 weeks. If you have any further comments or questions please get in touch, even if it is in an area that we haven't discussed yet.
- Please remember the ground rules when posting your comments.