

24-hour movement behaviours in 3 to 4 year old children in sub-Saharan Africa

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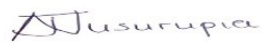
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April 2026

Declaration of contribution to the thesis

The data used in studies 2 and 3 of this thesis were based on an established international collaborative research project, the SUNRISE international study. In all studies detailed within this thesis, the majority of the research efforts are directly attributable to me, under the supervision of Professor John J. Reilly, Dr Leyna Germana and Dr Xanne Janssen.

I led the work presented in this thesis, including local ethics application, recruitment and primary data collection in Tanzania, conducted all statistical analyses, including processing ActiGraph accelerometry data, and drafted manuscripts for publication in peer reviewed international journals. My supervisory team obtained funding, advised on study design and statistical analyses, and provided feedback on all written work presented in this thesis.

The work presented in this thesis also benefited from the supervisory support and the SUNRISE international study collaborations that were vital to the success of the project. Notably, my supervisors obtained funding for the work presented in this thesis and were involved in the formulation of research ideas. The SUNRISE Coordinating Centre provided data for the secondary analysis study and equipment for primary data collection in Tanzania as well as supported cleaning and management of the Tanzania study data. All authors for the published and submitted work, where listed, contributed to data acquisition, provided critical inputs to draft manuscripts, and approved final versions. The relevant contributions for each author to the published work presented in this thesis is acknowledged in the respective chapter.

Jackline Jema Nusurupia

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Abstract

Tanzania, like other sub-Saharan African (SSA) countries, is undergoing rapid urbanisation and economic transition, potentially leading to lifestyle changes such as reduced physical activity, increased sedentary behaviour, and poorer nutritional intake. These shifts elevate the risk of obesity and associated non-communicable diseases (NCDs) both nationally and globally. In response, the World Health Organization's 2019 global 24-hour movement behaviour guidelines for children under five aimed to promote healthy growth and development and mitigate obesity and NCD risks. However, there remains limited evidence regarding guideline compliance in SSA, particularly in Tanzania, and no studies have explored feasible measurement methods suitable for large scale surveillance. Guided by the Behavioural Epidemiology Framework (BEF), this thesis contributes novel evidence on 24-hour movement behaviours namely physical activity, sedentary behaviour, and sleep among 3–4 year olds in low- and middle-income countries (LMICs). Chapter 2 presents a systematic review that identified substantial gaps in the existing literature from SSA. To address these gaps, chapter 3 reports findings from the SUNRISE pilot study conducted in Tanzania, which demonstrates the feasibility of employing accelerometers and proxy report questionnaires for large scale data collection. Preliminary results indicate high compliance with physical activity guidelines but lower compliance with sedentary and sleep guidelines, revealing possible disparities between urban and rural settings. Chapter 4 expands on this investigation by examining prevalences and correlates of meeting the 24-hour movement behaviour guidelines including urban rural differences across 10 LMICs. No statistically significant differences were observed in the proportion of children meeting the guidelines between urban and rural settings after controlling for sex, age and socioeconomic status.

Collectively, this thesis makes a new and valuable contribution by providing baseline data to inform the development of practical surveillance systems and targeted interventions in Tanzania, with potential applicability to SSA and LMICs more broadly. The evidence generated is useful for informing culturally sensitive strategies designed to promote healthier behaviours and reduce the risk of obesity and NCDs among young children, particularly in the context of ongoing socioeconomic transitions.

Acknowledgements

I am thankful to God for His infinite grace. This journey has been filled with challenges, yet my faith in Him has given me steadfast hope. I am grateful to my primary supervisor, Professor John Reilly, for his meticulous supervision and insightful feedback. His guidance has been invaluable. I extend my appreciation to the other supervisors; Dr. Leyna Germana and Dr. Xanne Janssen for their support, encouragement, and rigorous academic guidance. Their expertise has significantly enhanced my development as a researcher.

My thanks go to the Student Loans Company England, Greater Glasgow and Clyde Health Board, and the SUNRISE team at the University of Wollongong for financial support that made this doctoral study possible. I am equally indebted to my family in Tanzania, England, and Scotland-thank you for your unwavering love, belief in me, and both emotional and financial support. I owe special thanks to my uncle, Jean Wyclif Chagiye, who brought me to the UK from Cuba and introduced me to the education system that would shape my future.

I acknowledge the Tanzania Food and Nutrition Centre (TFNC) for granting me leave to complete my studies. Your understanding provided the time needed to focus on my research. To all pilot study participants: thank you for your time and valuable contributions. Without you, this research would not have been possible.

Finally, this thesis is lovingly dedicated to the memory of my father, Commissioner John Emilius Nusurupia, who passed away in 2015. He always believed in my potential and inspired me to pursue doctoral studies even before I dared to envision it myself. Papa, this achievement is as much yours as it is mine.

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COVID-19 impact statement on PhD

My PhD journey has been shaped by a series of substantial disruptions, most notably the COVID-19 pandemic, financial difficulties, and national obligations during Tanzania's 2020 general election. While these external challenges affected the timing, design, and implementation of my studies, they also provided opportunities for growth, strategic redirection, and the development of resilience and adaptability.

I began my doctoral studies in September 2019 and made encouraging progress during the first six months. I focused on completing Study 1-a systematic review titled *"Preschool children's compliance with the WHO 24-hour movement behaviour guidelines: A systematic review of Sub-Saharan African studies"* which formed a solid foundation for the rest of the thesis. My initial plan was to commence data collection for Study 2 in 2021, assessing the feasibility of the SUNRISE protocol in Tanzanian daycare centres. However, these plans were abruptly disrupted by the emergence of the COVID-19 pandemic. National lockdowns and health restrictions made it impossible to access early childhood education centres, recruit participants, or obtain research funding within the expected timeframe. The uncertainty and logistical challenges introduced by the pandemic led to significant delays in launching the pilot study.

In response to these delays and to maintain research productivity and thesis progression, I undertook a secondary analysis study using available data from the SUNRISE global database. This became Study 3 in my thesis. The decision to pursue this secondary analysis was directly influenced by the disruptions caused by COVID-19 and the consequent delays in primary data collection. This decision allowed me to remain productive, meet academic milestones, and contribute to the global evidence base on 24-hour movement behaviours in LMICs. This study not only served as a timely and meaningful alternative but also enriched my thesis with valuable international comparative insights, particularly relevant to the Tanzanian context. In this way, the study both filled a gap created by COVID-related delays and added significant value to the thesis as a whole.

Beyond the research design, the pandemic posed broader challenges to my academic development. Travel restrictions and the shift to virtual platforms limited opportunities for in-person conferences, networking, and collaborative learning, elements that are often

vital for early-career researchers. While I participated in various online training sessions and conferences, the lack of face-to-face interaction restrained informal knowledge exchange and reduced my exposure to diverse academic perspectives. Nonetheless, I maximised the use of digital tools and online resources to sustain academic progress.

Other disruptions also arose. In October 2020, during Tanzania's general election, I was called upon to fulfil mandatory responsibilities as a government employee. These duties temporarily diverted my focus from academic activities. Later, financial difficulties led me to suspend my studies voluntarily between March and September 2022 in order to resolve outstanding tuition fees. Recognising the need for greater flexibility, I then transitioned from full-time to part-time study in December 2022, allowing me to better balance my professional, financial, and academic commitments.

Despite these challenges, I have remained committed to completing my PhD. I am proud to have published three peer-reviewed papers as part of my thesis, reflecting both the academic contribution and personal resilience that have defined this journey. Overcoming these disruptions has ultimately strengthened my determination and enhanced my capacity to adapt, qualities that I believe will continue to serve me well in my future academic and professional career.

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List of abbreviations

2SD	Two Standard Deviation
ACSE	Advanced Certificate of Secondary Education
BEF	Behavioural Epidemiology Framework
BMI	Body Mass Index
CAGR	Compound Annual Growth Rate
CCM	Chama Cha Mapinduzi
CDC	Center for Disease Control and Prevention
CI	Confidence Interval
CoP	Cut-off-Point
CPI	Corruption Perception Index
CPM	Counts Per Minute
CSE	Certificate of Secondary Education
CVDs	Cardio Vascular Diseases
DHS	Demographic Health Survey
ECD	Early Childhood Development
ECEC	Early Childhood Education Centre
ECHO	Ending Childhood Obesity
GAPPA	Global Action Plan on Physical Activity
GDP	Gross Domestic Product
HBS	Household Budget Survey
HDI	Human Development Index
HICs	High-income Countries
ICC	Intra-Class Correlation
ICAD	International Children's Accelerometry Database
IOTF	International Obesity Task Force
LGA	Local Government Authority
LMICs	Low -and Middle - Income Countries
LPA	Light intensity Physical Activity
MDG	Millenium Development Goal
METs	Metabolic Equivalents
MMR	Maternal Mortality Ratios

MPA	Moderate-intensity Physical Activity
MVPA	Moderate-to-Vigorous-intensity Physical Activity
NCD	Non-Communicable Disease
NHS	National Health Service
NGO	Non-Governmental Organizations
OR	Odds Ratio
OSRAC-P	Observation System for Recording Physical Activity in Children - Preschool version
PA	Physical Activity
PE	Physical Education
PHC	Population and Housing Census
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
RCT	Randomised Controlled Trial
SB	Sedentary Behaviour
SBRN	Sedentary Behaviour Research Network
SEM	Social Ecological Model
SES	Socioeconomic Status
SSA	sub-Saharan Africa
SUNRISE	International Study of Movement Behaviours in Early Years
TFNC	Tanzania Food and Nutrition Centre
TGMD-3	Test of Gross Motor Development Third Edition
TDHS	Tanzania Demographic Health Survey
THBS	Tanzania Housing Budget Survey
TPA	Total Physical Activity
U5	Under five
UK	United Kingdom
UPE	Universal Primary Education
VPA	Vigorous intensity Physical Activity
WHO	World Health Organization
WOF	World Obesity Federation

Chapter 1: Introduction

1.0 An overview of Tanzania

The primary objective of the research presented in this thesis is to enhance the evidence base concerning movement behaviours and health in early childhood, with a focus on Tanzania and broader implications for SSA countries. Tanzania is located in East Africa within the Great Lakes region, shares its northern border with Uganda and Kenya, while the Indian Ocean and the Comoro Islands lie to the east. To the south, Tanzania is bordered by Mozambique and Malawi, with Zambia to the southwest. The western border is shared with the Democratic Republic of Congo, Rwanda, and Burundi. The country is divided into 31 regions, with five of those located in Zanzibar and the remaining 26 on the mainland. **Figure 1-1** is a map of Tanzania illustrating Tanzania's geographical location and the countries that share borders. (source: Tanzania Government Online, 2024).

Map of Tanzania

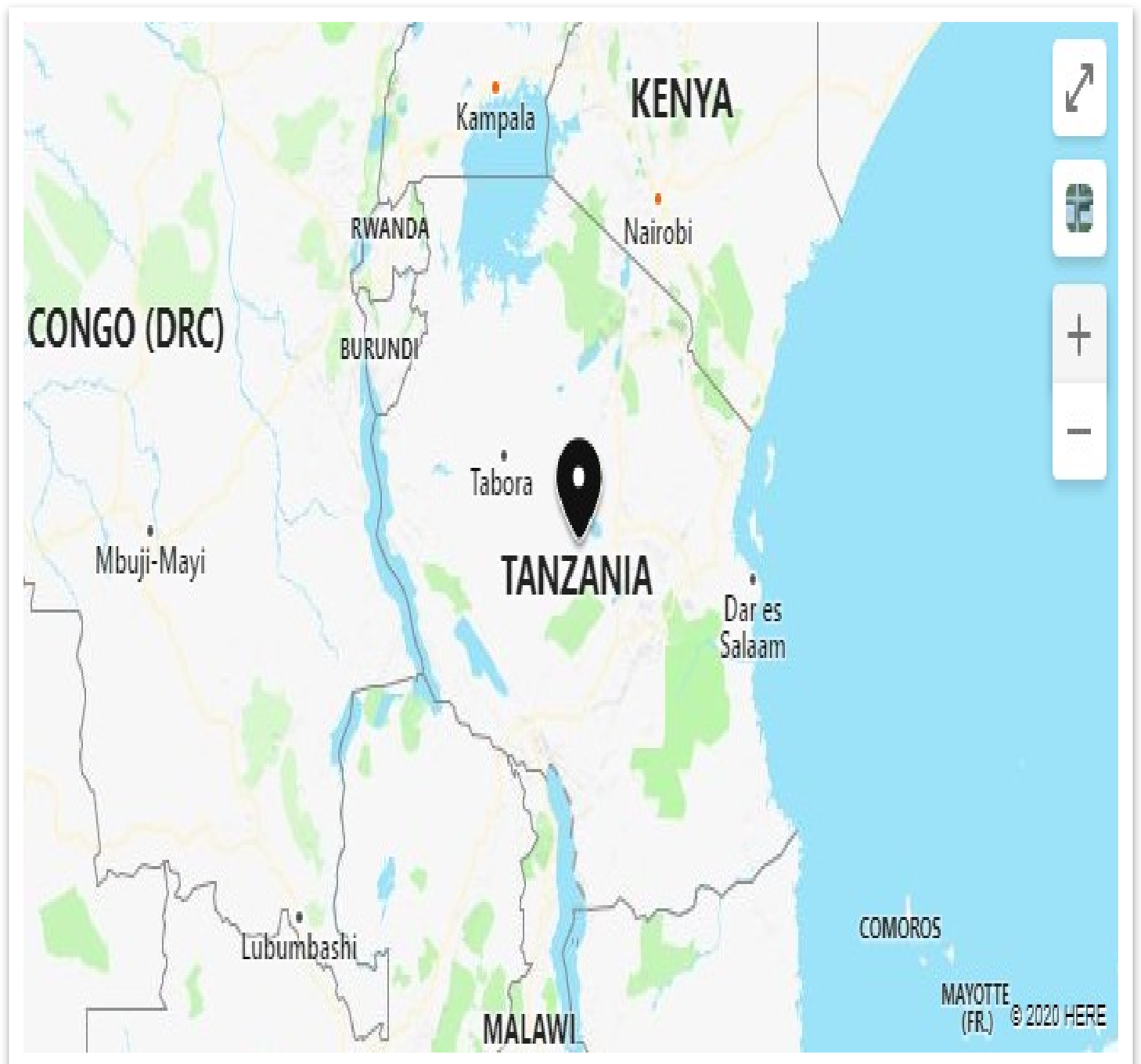


Figure 1-1: Map of Tanzania (Tanzania Government, online)

Tanzania is the most linguistically diverse nation in East Africa, with over 100 different languages spoken (Ammon, Dittmar, & Mattheier, 2006). Swahili is the national language, with about 10% of Tanzanians speaking it as their first language and approximately 90% as their second language (Masato, 2004). Swahili is the language used in primary schools, parliament, and the lower courts. English is widely used in secondary schools, higher education institutions, higher courts, diplomacy, and international trade.

Politics in Tanzania is significantly influenced by religion. Besides the dominant ruling party, Chama Cha Mapinduzi (CCM), many other political parties tend to rely on regional appeals and ethnic or religious sentiment to gain electoral support (Egboh & Aniche, 2015). In March 2021, Samia Suluhu Hassan became the sixth President of Tanzania following the death of President John Magufuli. As his Vice President, she assumed office by the Tanzanian constitution, which stipulates that the Vice President assumes the presidency if the sitting President passes away or is otherwise unable to serve.

1.1 Challenges to achieving sustainable development in Tanzania

Despite Tanzania's rich natural resources, diverse culture, and economic potential, it faces several challenges that hinder its development. These challenges are related to poverty, healthcare access, governance infrastructure, social equity, and education, particularly in rural areas. Sustainable economic growth is one of the major challenges Tanzania faces. Despite economic growth of 5.2% in 2023 (worldbank.org), poverty levels remain high, especially in rural areas. According to the Tanzania Household Budget Survey (THBS 2018), it is estimated that over 63% of the population is employed in the agricultural sector, which faces challenges such as low productivity, limited access to markets, and vulnerability to climate change. The majority of farmers practice subsistence farming, which makes it difficult for them to transition to more commercialised and profitable practices.

Another challenge that Tanzania faces is the lack of access to healthcare, particularly in rural areas, where over 65% of the population resides (Population and Housing Census; PHC, 2022). Currently, the healthcare system is severely underfunded, which results in shortages of medical personnel, essential medicines, and adequate medical facilities. According to a report produced by the Ministry of Health and Social Welfare, Tanzania had a doctor to patient ratio of 1:25,000 in 2015, which was well below the recommended ratio of 1:1,000 (WHO 2010).

Many rural health centres lack qualified medical professionals, with many clinics operating without doctors and relying on nurses or medical assistants. Furthermore, the geographical spread of healthcare facilities makes it difficult for people living in remote areas to access basic medical services. Consequently, maternal and child mortality rates are exacerbated, as well as the burden of infectious diseases such as malaria, tuberculosis, and HIV/AIDS.

The issue of social equity remains a major challenge in Tanzania, as there are significant disparities between urban and rural populations in regard to income, access to services, and opportunities. For example, in terms of health services, there was an uneven distribution of hospitals and dispensaries in the colonial era, which sowed the seeds of inequities in health care services (Allen, 2002; Shivji, 2009).

According to the Corruption Perception Index (CPI), no government is completely free of corruption. The index revealed that two-thirds of countries globally scored below 50, which indicates that corruption is still a serious problem (Transparency International, 2023). As with all governments, the Tanzanian government is not immune to corruption and bureaucracy, which impede the delivery of effective public services and the development of the country's citizens. According to the 2024 CPI, Tanzania scores 40 in terms of corruption perception, placing it 87th globally (transparency.org). As a result of widespread corruption, efforts to improve public services, such as healthcare and education, are continuing to be undermined. For instance, funds allocated for health and education programmes are often misappropriated, reducing the effectiveness of government initiatives.

Several additional factors hinder Tanzania's development, including the lack of adequate infrastructure, such as poor road networks, limited electricity, and underdeveloped communication systems. These challenges are particularly evident in rural areas, where communities lag behind in almost all development indicators compared to urban centres such as Dar es Salaam, Arusha, and Mwanza. Rural-urban disparities exacerbate inequality, with rural residents often lacking access to basic services readily available in urban areas. The poor state of rural roads restricts access to markets, education, and healthcare, making it difficult for farmers to transport their produce to urban centres and contributing to persistent rural poverty. Additionally, rural electrification remains low despite government efforts to expand access, which in turn hampers the delivery of education and healthcare services and limits economic opportunities. As a result of these persistent social and infrastructural inequalities,

women and children in rural areas are particularly disadvantaged, facing limited access to quality education, healthcare, and means for economic advancement.

Limited access to electricity significantly impedes business operations and adversely affects both the education and healthcare sectors. In educational institutions, the lack of reliable electricity hinders the effective integration of technology into teaching and learning processes. Similarly, in healthcare facilities, it restricts the utilisation of essential medical equipment, thereby undermining service delivery. In rural areas, this infrastructural limitation also results in reduced access to screens and internet connectivity. Consequently, children in these settings are less likely to be exposed to screen-based devices such as televisions, computers, and smartphones compared to their urban counterparts. This disparity might have important implications for sedentary behaviour and screen time, both of which are key components of the 24-hour movement behaviour guidelines. According to the Director General of the Commission for Science and Technology (COSTECH), Amos Nungu, in 2021, approximately 86% of individuals in rural areas lacked internet access, compared to 45% in urban areas. This disparity also has possible implications for sedentary behaviour, including screen time in children.

1.2 Inequality in health services in Tanzania

Differences in socio-economic and geographical regions contribute to the uneven distribution of access to health services, including health professionals. This disparity leads to variations in under five year old mortality rates across regions. Numerous complex factors, such as differences in population density and the availability of referral hospitals, drive these inequalities. Referral hospitals are more economically efficient as they concentrate resources on those most in need (Smithson, 2006). However, many of these inequalities are preventable. In Tanzania, the allocation of medical resources to local government authorities is based on a formula: 70% of the expenditure is allocated according to district population, 10% based on under five mortality rates, 10% according to poverty levels, and the remaining 10% based on the distance covered by medical vehicles. Despite this formula, there is a notable discrepancy between the resources allocated and those received (Sikika, 2012).

Similarly, inequalities in health services can also be seen in two levels (Munga and Maestad, 2009); there are large disparities in the number of health workers per capita across districts with a 40-fold differences between districts at the high and the low ends of distributional inequalities. Highly skilled, trained health workers are unequally distributed in a similar trend.

Districts with few health workers per capita, likewise, have disproportionately few highly trained health workers.

1.3 Tanzanian economy

Tanzania was ranked among the 15 poorest countries globally, with a GDP per capita of approximately \$1,037 in 2022. The country's human development index, which measures progress in health, education, and living standards, is 0.528, ranking the country 159th globally. While the government has implemented initiatives to improve key social services, including health, education, and water access, rapid population growth continues to challenge these efforts, making it difficult for the government to keep pace.

According to the Household Budget Surveys (HBS) in Tanzania, the "poor" have been defined as individuals whose consumption falls below the national poverty line, meaning they are unable to meet their basic consumption needs. In Tanzania, significant efforts were made between 2007 and 2016 to reduce poverty, leading to a decrease in the poverty rate from 34.4% to 26.8% (HBS, 2018). However, rapid population growth has offset these gains, with the absolute number of people living in poverty now reaching around 15 million (World Bank, 2024). In the 2015 report by the World Bank, it was pointed out that approximately 70% of Tanzanians were living on less than two dollars per day. **Figure 1–2** also illustrates Tanzania's GDP growth rate for Q4 2014–2021.

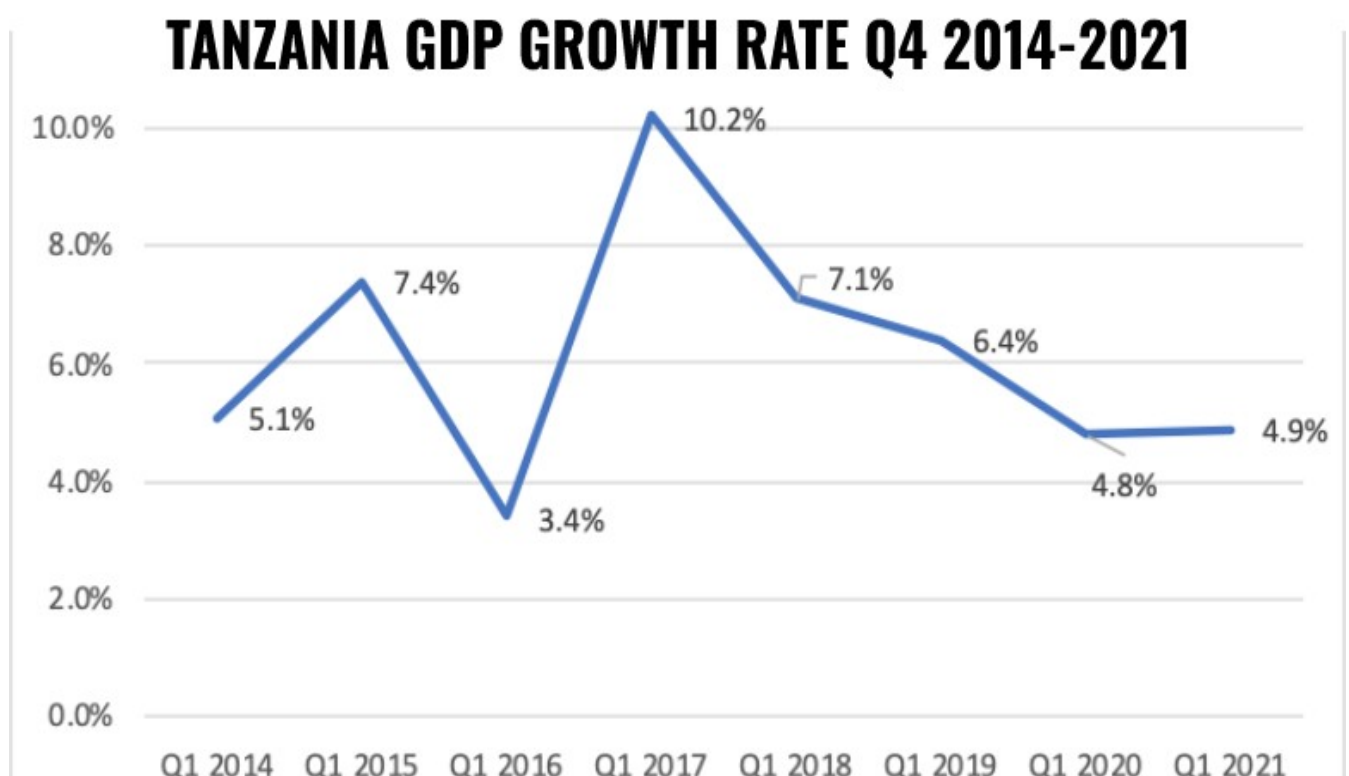


Figure 1- 2: Trends in Tanzania's GDP per capita and GDP growth rate (Q4 2014–2021). Source from TanzaniaInvest.com.

1.4. The population and demographics of Tanzania

According to data from the United Nations Department of Economic and Social Affairs - Population Division, as of April 2025, the population of Tanzania was 70,110,125, representing 0.86% of the global population. Tanzania is the 21st most populous country in the world, with a population density of approximately 206 individuals per square mile across a total land area of 342,009 square miles. Approximately 40% (28,244,987) of the population resides in urban areas. The country has a notably young population, with a median age of 17.5 years (Worldometer, n.d.). Tanzania also ranks among the countries with the highest fertility rates globally, averaging 4.5 live births per woman. According to the 2022 Population and Housing Census (PHC), there are 9,484,171 children aged 0 to 4 years in Tanzania, representing 15% of the total population (PHC, 2022).

The life expectancy in Tanzania is 64.6 years for males and 70.2 years for females, with an overall average of 67.4 years. This positions Tanzania 148th in the world for life expectancy (Worldometer, n.d.). According to the PHC, the population has been increasing steadily at an annual rate of 3%, with the 2023 census estimating the population at approximately 69 million (PHC, 2022). The population is projected to reach around 81 million by 2030 (Worldometer, n.d.).

1.5 Education system

Tanzania's formal education system commences with two year of pre primary education at the age of five, followed by six years of primary schooling (National Bureau of Statistics, 2018). Children under five are not included within the formal education framework. There is an absence of a standardised national curriculum or formal provision for early learning at this age, particularly within governmental structures.

In 1995, the Tanzanian government introduced the pre primary policy, which was later incorporated into the comprehensive Education and Training Policy (MOEC, 2005). This initiative required primary schools to establish pre primary classes in partnership with local communities. While the government took on the responsibility for pre primary education for children aged 5 to 6, it encouraged non-NGOs and other non state actors to support early childhood education for children under five years old (Mtahabwa & Rao, 2009). As a result,

public provision of pre primary education for 3–4 year olds remained limited. The majority of children in this age group remained at home, and their access to early learning opportunities varies significantly based on household socioeconomic status and geographic location. Children from affluent families often enrol in private nursery schools run by a variety of stakeholders, including private providers, community-based organizations, NGOs, and faith-based institutions. These institutions exist outside the formal government education system.

Following independence, Tanzania identified ignorance, poverty and disease as primary impediments to development, prompting the implementation of the Universal Primary Education (UPE) reform during 1977–1978 (Sabates, Westbrook, & Hernandez-Fernandez, 2012). This initiative sought to render education both free and compulsory for children aged 7 to 13, resulting in a significant increase in literacy rates to 98% by the mid 1980s. However, these advancements were not sustained due to economic challenges, including escalating oil prices, drought, and the burden of debt repayment, which necessitated the introduction of the structural adjustment programmes. This programme established cost sharing in education, rendering schooling unaffordable for many families and contributing to elevated dropout rates.

1.6 Circumstances of young children (under 5) in Tanzania

1.6.1 Under 5 mortality rate

The current U5 infant mortality rate is 43 per 1,000 live births, marking a significant improvement from the early 2000s, when the rate exceeded 112 per 1,000 live births (TDHS -MIS 2022). A significant part of these improvements can be attributed to the government's implementation of high-impact health programmes, such as HIV prevention from mothers to children, immunization and other routine child health services, management of acute malnutrition, Vitamin A supplementation, growth and development monitoring, prevention and treatment of infectious diseases, and the provision of quality care for sick children. Despite these gains, most deaths among children U5 are still caused by preventable diseases (UNICEF, n.d.). The maternal mortality ratio (MMR) in Tanzania was 432 per 100,000 live births in 2012. Tanzania set an ambitious goal to achieve the Millennium Development Goal (MDG) target of reducing the MMR to 70 per 100,000 live births by 2030. While substantial progress has been made, with the MMR decreasing to 194 per 100,000 live births in 2022 (as reported in the Tanzania Demographic and Health Survey and Malaria Indicator Survey 2022), continued efforts are needed to achieve the 2030 target.

The socio-economic and geographical disparities in Tanzania result in significant differences in child mortality rates across the country.

These inequalities stem largely from uneven access to and utilisation of health services, including the availability of healthcare professionals. Consequently, under five mortality rates vary widely by region. For instance, while the northern regions of Tanzania have U5 mortality rate of 56 per 1,000 live births, the lake regions experience a much higher rate, with up to 88 deaths per 1,000 live births (UNICEF, n.d.).

1.7 Movement behaviours in Tanzanian children aged 3 to 4 years: A foundation for understanding childhood obesity

SSA, including Tanzania, is experiencing rapid urbanisation. Together, these changes predispose children to gain excess weight and increase the risk of NCDs (Muthuri et al., 2014). Approximately one third of urban children in Africa are reported to exhibit excessive body fat, indicating increased risk of associated health complications (Diouf et al., 2018). Furthermore, childhood overweight and obesity are increasingly recognised as significant public health concerns in the region (Gebremedhin, 2015). In response to these trends, the World Health Organisation, through its Ending Childhood Obesity (ECHO) Report, called for urgent, coordinated action to address low physical activity, high levels of sedentary behaviour, and insufficient sleep among young children as part of comprehensive obesity prevention and management strategies (WHO, 2016).

A growing body of research indicates that obesity and its associated risk factors originate early in life, particularly during the critical period of early childhood (Balbus et al., 2013; Simmonds et al., 2016). Recognising both the importance of this developmental stage and the escalating global prevalence of obesity, the World Health Organisation introduced the WHO guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children Under 5 Years of Age in 2019. These guidelines marked a significant shift in perspective by integrating physical activity, sedentary behaviour (including screen time), and sleep within a 24-hour framework, acknowledging that these behaviours are interdependent and collectively influence health and development in early childhood (WHO, 2019). While earlier research has largely focused on individual behaviours, most notably physical activity (Reilly et al., 2022; Okely et al., 2018), there is now increasing recognition that the overall composition and balance of movement behaviours across the day are crucial for optimal growth and development (WHO, 2019).

Despite the publication of these global 24-hour movement guidelines more than five years ago and continued international efforts to achieve the 2030 physical activity targets worldwide (WHO, 2022), evidence on young children's compliance with these guidelines remains limited in many LMICs (Arts et al., 2023), particularly in SSA (Nusurupia et al., 2020). Furthermore, surveillance systems for monitoring these behaviours are uncommon even in high-income countries and are virtually absent across much of sub-Saharan Africa (Aubert et al., 2021; Reilly et al., 2022).

Guided by these global priorities, this thesis is grounded in the Behavioural Epidemiology Framework (BEF), which offers a systematic approach to advancing research on health-related behaviours. The BEF delineates a sequence of interconnected phases, including establishing links between behaviours and health outcomes, developing valid and reliable measurement tools, identifying behavioural correlates and determinants, evaluating interventions, and translating evidence into policy and practice (Sallis et al., 2000; Bauman et al., 2012; Sallis et al., 2015). By structuring research in this manner, the framework ensures a coherent progression from foundational understanding to real-world application. Complementing this, the socioecological model (SEM) provides a multi-level lens through which correlates are understood, spanning individual, interpersonal, organisational, community, and policy domains, thereby enriching interpretation of determinants within each phase of the BEF and strengthening its application to complex real-world contexts (McLeroy et al., 1988; Sallis et al., 2008)

Although the BEF has been widely applied in physical activity research, particularly in high-income countries, its use in early childhood populations and LMIC settings remains relatively limited (Rao et al., 2019). This lack of recent application highlights a significant gap in the literature and underscores the contribution of the present thesis. It suggests that, despite its relevance, the framework has not yet been fully operationalized in contexts where it is most needed to inform policy and intervention efforts (Munoz-Chereau et al., 2021).

1.8 Overweight and obesity

1.8.1 Definitions of obesity and overweight

Childhood and adolescent overweight and obesity are increasingly acknowledged as significant public health issues, with strong associations to both immediate and long-term adverse health outcomes (Reilly et al., 2003).

The World Health Organization (WHO, 2024) describes being overweight as having an excess of fat deposits, while obesity is characterised by an accumulation of fat that can adversely affect health. Although this general definition applies across all age groups, including children under five, the clinical and epidemiological implications vary by age and developmental stage. For younger children, definitions must be age specific, given that growth and body composition change rapidly during early childhood (WHO, 2021).

The severity and health impact of childhood obesity differ significantly from those of being overweight, with evidence indicating a dose response relationship: the greater the degree of excess body fat, the higher the risk of adverse health outcomes (Hasan et al., 2020; Sharma et al., 2018). Lobstein et al. (2015) also emphasise that obesity represents a more pronounced deviation from normal weight status than being overweight and is linked to more significantly elevated health risks. Several key health risks associated with childhood and adolescent obesity include metabolic syndrome, type 2 diabetes, and non-alcoholic fatty liver disease (Hossain et al., 2022; Hruby et al., 2016). Furthermore, childhood and adolescent obesity is a well-established risk factor for future cardiovascular disease (CVD), primarily through the initiation of early pathological processes that predispose individuals to long-term cardiovascular complications (Barton, 2012; McPhee et al., 2020). Summerbell et al. (2005), and WHO (2000) further argued that childhood obesity has a more profound impact on long-term health than being overweight, underscoring the necessity for precise and consistent identification and classification of these conditions.

According to De Onis et al. (2007), the categorisation of children's weight status is generally based on growth reference standards or charts. These tools are crafted to consider factors such as age, sex, and developmental stage, ensuring an accurate and age-appropriate assessment of nutritional status. Hence, it is important to clarify the age specific criteria used by the WHO when defining overweight and obesity in childhood, as these differ depending on the child's age. According to the WHO (2006), for children under five, being overweight is defined as having a weight-for-height that exceeds 2 standard deviations above the median, while obesity is defined as weight-for-height that is more than 3 standard deviations above the median.

This means that the child's BMI is significantly higher than what is regarded as usual for their age and sex.

In contrast, for children and adolescents aged 5 to 19 years, the WHO (2007) Growth Reference defines overweight as a BMI-for-age that corresponds to the 85th percentile but below the 97th percentile, and obesity as a BMI-for-age above the 97th percentile on the WHO growth reference curve. For children under 5 years, the WHO (2006) Growth Standard defines obesity as a BMI-for-age more than two standard deviations above the median of the WHO growth standard. These age specific cut-offs, based on internationally developed growth references, are used globally to monitor and compare trends in childhood overweight and obesity. As highlighted by WHO (2020), such definitions are essential for tracking changes over time, identifying populations at risk, and guiding the development of targeted public health interventions.

Several systematic reviews have highlighted the significant adverse health outcomes associated with childhood and adolescent obesity (Simmonds et al., 2016; Reilly et al., 2003). Reilly (2010) and Reilly & Kelly (2011) note that these health outcomes can also manifest later in life. Biro & Wien (2010) and Reilly (2010) particularly observe that childhood obesity not only tends to persist into adolescence and adulthood but also perpetuates a cycle of adverse health outcomes over the lifespan. During this progression, the condition tends to affect several of the body's systems, including the metabolic, cardiovascular, musculoskeletal, respiratory, and endocrine systems (Centres for Disease Control and Prevention [CDC], 2024; WHO, 2024).

Excessive body fat during childhood, has been shown to impose significant strain on the cardiovascular system. Evidence indicates that children with obesity are at increased risk of developing early onset hypertension and structural cardiac changes, including left ventricular hypertrophy (Brady et al., 2016). These alterations not only represent early markers of cardiovascular disease but also have the potential to persist into adulthood, amplifying long-term morbidity. In addition to cardiovascular consequences, the mechanical burden of carrying excess body mass places considerable strain on the musculoskeletal system. This increased mechanical load has been linked to a range of complications, including joint pain, reduced mobility, and altered gait patterns (Paulis et al., 2014). Furthermore, chronic overloading of weight bearing joints, particularly the knees and hips, accelerates cartilage wear and may precipitate early onset osteoarthritis, a condition historically associated with older adults but now increasingly recognised in younger populations affected by obesity (Reilly et al., 2010).

These musculoskeletal consequences not only limit a child's capacity for physical activity but can also contribute to a vicious cycle of further weight gain and declining functional health.

In addition to physical health concerns, childhood obesity can also have critical psychological and social implications for the individual. To this end, Kelsey et al. (2014) and Reilly & Kelly (2011) mention that children or adolescents who are affected by overweight or obesity are more likely to experience low self-esteem, social stigmatisation, bullying and depression, all of which can hinder their social development (Puhl & Latner, 2007). As highlighted in systematic reviews (Reilly et al., 2003; Reilly & Kelly 2011; Schroeder et al., 2021), the physical and mental health challenges associated with childhood obesity often extend into adulthood, contributing to long-term mental health issues such as anxiety, chronic depression, and reduced quality of life. Furthermore, longitudinal studies indicate that these burdens may be compounded by ongoing weight related discrimination and challenges in social and occupational settings, further exacerbating their impact on overall well-being (Jackson, Beeken, & Wardle, 2015).

1.8.2 Prevalence of Obesity in Sub-Saharan Africa

The prevalence of obesity among children under the age of five has risen steadily worldwide over the past three decades, with considerable variation in both levels and trends across regions. According to the WHO, there were approximately 38 million children under five who were classified as having obesity worldwide in 2019 (WHO, 2020). In Africa, this upward trend has been particularly striking, with the number of children under five affected by overweight and obesity nearly doubling from 5.4 million in 1990 to 10.3 million in 2016, highlighting the growing magnitude of the problem across the continent (WHO ECHO, 2016). This alarming trend has been recognised as a pandemic threat, prompting WHO member states to endorse global nutrition targets aimed at improving maternal, infant and young child nutrition. One of these targets was to ensure that there is "no increase in the prevalence of overweight children" by the year 2025 (WHO 2014).

Historically, undernutrition has been the predominant nutritional concern in SSA due to its high prevalence. However, recent evidence indicates a rising prevalence of childhood overweight and obesity in the region, with disproportionately higher rates observed in urban areas and among children from more affluent socioeconomic backgrounds (Islam et al., 2024).

This emerging trend has been largely attributed to rapid urbanisation, shifts in dietary patterns towards energy-dense and highly processed foods, and declining levels of physical activity (Popkin et al., 2020). As a result, many countries in SSA are increasingly facing the double burden of malnutrition, where undernutrition coexists with overweight and obesity (Caballero, 2005; Popkin & Gordon-Larsen, 2004). According to the Global Nutrition (2023) Report, SSA continues to experience a substantial malnutrition burden among children under five years of age. The average prevalence of overweight in this age group is approximately 5%, representing the second lowest rate across global regions. However, the prevalence of stunting (chronic undernutrition) remains high at 31%, which is considerably higher than the global average of 22%. In contrast, the prevalence of wasting (acute undernutrition) is estimated at 6%, slightly lower than the global average of 7%. (Global Nutrition Report, 2023) Together, these figures highlight the coexistence of persistent undernutrition alongside the emerging challenge of childhood overweight and obesity-overnutrition- in the region.

Across SSA, estimates of obesity prevalence have largely been derived from Demographic and Health Surveys (DHS) and nationally nutrition surveys, including those collated by UNICEF (UNICEF 2013). These studies predominantly utilised WHO growth references, facilitating comparison with global estimates such as those by de Onis et al. (2010). Nevertheless, concerns have been raised regarding the adequacy of BMI-for-age as a proxy for body fat, given its prevalent use in African studies. A recent systematic review and meta-analysis conducted by Shibeshi et al. (2026) examined the prevalence data on overweight and obesity among children aged 2-5 years in all 48 countries of Sub-Saharan Africa, utilising BMI-for-age z-scores in accordance with WHO growth standards. The review drew on evidence from community-based surveys, health facility records, and nationally representative studies, including Demographic and Health Surveys (DHS), in order to provide comprehensive population-level estimate. The findings revealed considerable variation across countries within the region. Relatively low pooled prevalence rates of overweight and obesity were reported in Malawi (4%), Uganda (5%), and Ghana (5%). In contrast, substantially higher prevalence was observed in Kenya (22%) and South Africa (21%). Several countries fell between these extremes, with estimates of approximately 13% reported in Ethiopia and Cameroon, and 17% in Nigeria. These figures underscore the substantial variation in obesity prevalence across the region (Shibeshi et al., 2026). The review highlighted that these disparities likely mirror the uneven pace of social and economic transitions across countries.

In contexts with higher prevalence of overweight and obesity, such as Kenya and South Africa, rapid urbanisation, increased access to processed and energy-dense foods, and increasingly sedentary lifestyles have been observed (Shibeshi et al., 2026). Such changes, often associated with economic development, can disrupt traditional dietary habits and patterns of active living, contributing to rising obesity rates.

In summary, while childhood and adolescent obesity prevalence has increased globally, the trend shows signs of stabilisation in certain Western countries but continues to escalate in others, especially in developing and transitioning economies. The heterogeneity in obesity trends underscores the necessity of region-specific public health strategies and policies to address this growing epidemic effectively (González-Álvarez et al., 2020; Zhang et al., 2024).

1.8.3 The prevalence and trends of childhood obesity in Tanzania

The above section has provided an overview of global obesity prevalence among children and adolescents; now the focus will shift to Tanzania, since the present thesis will be focusing on the Tanzanian context. Tanzania has been implementing various strategies and policies that aim at preventing and addressing childhood obesity.

Some of these include the promotion of healthy diets, encouraging the consumption of nutritious foods while limiting sugary and high fat foods, and physical activity campaigns that raise awareness and encourage children to meet WHO guidelines for physical activity (TFNC, 2021). The country has integrated school health programmes focusing on nutrition education and physical activity, and early childhood development programmes (UNICEF, 2020). Moreover, interventions rooted in the community are important in tackling childhood obesity. These initiatives involve local leaders, parents, and caregivers to encourage healthy habits and establish environments that support children's well-being, as highlighted in population-based approaches to childhood obesity prevention (WHO 2012). These interventions often include school-based nutrition programmes, physical activity initiatives, and public awareness campaigns that emphasise the importance of a balanced diet and active lifestyle (UNICEF, 2020; TFNC, 2021). Such multi sectoral approaches align with global recommendations from the WHO, which advocates comprehensive obesity prevention strategies that involve education, healthcare, and policy support to address the root causes of unhealthy weight gain in children (WHO, 2016).

Despite these efforts, there is still a substantial challenge in effectively tackling childhood obesity in Tanzania; limited access to healthcare services, socioeconomic disparities, and cultural perceptions of child body weight contribute to the persistence of childhood obesity (United Republic of Tanzania, Ministry of Health, Community Development, Gender, Elderly and Children, 2021). Additionally, the rapid urbanisation and nutrition transition in many parts of Tanzania have led to increased consumption of processed foods high in sugar, salt, and unhealthy fats, further exacerbating the problem (Popkin et al., 2022). School-based and community-led interventions often face barriers such as inadequate funding, inconsistent implementation, and a lack of trained personnel to deliver effective health promotion programmes (TNFC, 2021). Therefore, in order to describe the scope of the problem and the impact of policy efforts, it is important to understand the prevalence and trends of childhood obesity within Tanzania.

Every five years, the Tanzania Demographic and Health Surveys (TDHS) are conducted, which collect and disseminate data on the Tanzanian population and health. One of the key indicators being evaluated in the TDHS is the nutritional status of children under five years of age. This indicator is being assessed by measuring children's BMI and comparing the results to the WHO's 2006 child growth standards. These data help identify issues of malnutrition, including both undernutrition, and overnutrition and how rates change over time across various demographics.

The most recent Tanzania Demographic and Health Survey (TDHS) 2021–22 reported that 4.0% of children under five years of age were classified as overweight (including those with obesity). This classification refers to children with a weight-for-height z-score greater than +2 standard deviations above the median of the reference population, as defined by WHO child growth standards (WHO, 2006) (TDHS, 2022). The data indicate a slight increase from the 2015–16 TDHS, which reported a prevalence of 3.7% within the same age group. However, the survey reports did not provide confidence intervals for these estimates, limiting the ability to determine whether this increase is statistically significant. Despite the relatively low prevalence, the observed rise suggests a gradual upward trend in overweight among young children (TNFC, 2021). Continued surveillance and a better understanding of the underlying determinants are therefore important for informing effective public health strategies and interventions.

However, it is important to note that the TDHS does not explicitly provide data on obesity (just overweight including obesity) in young children, making it difficult to fully understand the burden of excess body weight or body fat in this age group. Given the uncertainty around any prevalence estimate, and with no confidence intervals for prevalence estimates given in the TDHS, these figures are probably not significantly different, and the surveys' confidence intervals for these estimates likely overlapped, thereby indicating no substantial difference between urban and rural areas.

It is also important to note that the TDHS reports overweight as a combined category that includes obesity, rather than providing separate estimates for obesity alone. This makes it difficult to fully assess the specific burden of obesity as defined by high BMI-for-age among children under five years of age in Tanzania.

Socioeconomic disparities in overweight prevalence were more pronounced in the TDHS. Overweight prevalence was highest among children from the wealthiest households (5.2%) compared to those from the poorest households (2.8%) (TNFC, 2021). This trend agrees with patterns observed in other LMICs countries facing emerging public health challenges related to overweight and obesity (WHO, 2024).

Studies have shown that in high-income countries, risks associated with childhood obesity are disproportionately higher in families with lower socioeconomic status (SES) while in LMICs, the opposite trend is observed with higher obesity prevalence among children from high SES families (Vazquez & Cubbin, 2020). In wealthier families, greater access to energy dense, unhealthy foods and beverages often contributes to higher rates of overweight and obesity (Ofori-Asenso et al., 2016).

It is important to note that while the present thesis has a focus on 3–4 year olds, childhood obesity research in Tanzania remains limited, particularly for this age group. Most available studies, typically surveys and landscape analyses, have focused on older age groups and/or specific settings, and this has left a gap in understanding the prevalence and determinants of obesity in early childhood. Notable studies on overweight and obesity prevalence among children under five years of age in Tanzania include the TDHS, whose reports cover the period from 2021-22 (United Republic of Tanzania, 2022), and landscape analyses on overweight and obesity that have been conducted by the TFNC.

TFNC's efforts span multiple years including a strategic plan covering the period from 2014 to 2018 (TFNC), 2014 and a recent landscape analysis conducted in liaison with UNICEF in 2021 (TFNC 2021).

There is a paucity of data concerning childhood obesity among 3–4 year olds in Tanzania. Nevertheless, research focusing on older children indicates an increasing prevalence of overweight and obesity within school aged populations. For instance, a cross-sectional study conducted in Dar es Salaam examined the prevalence and determinants of obesity in children and adolescents aged 6 to 17 years. Utilising the WHO growth reference (2007), obesity was defined as a BMI-for-age z-score exceeding +2 SDs above the median. The study reported an overall obesity prevalence of 5.2%, with a higher prevalence among girls (6.3%) compared to boys (3.8%) (Muhihi et al., 2012). Similarly, a study conducted in Morogoro Municipality among individuals aged 7 to 12 years reported a higher overall prevalence of overweight and obesity, reaching 19.0%. The prevalence was significantly higher among students attending private schools (24.8%) compared to those in public schools (14.2%). Comparable rates were observed between rural (17.6%) and urban (20.0%) settings. This study employed the WHO (2009) growth reference cut-offs for children and adolescents aged 5 to 19 years, classifying overweight as a BMI-for-age between the 85th and 95th percentiles, and obesity as $\geq 95^{\text{th}}$ percentile (Muhomba et al., 2023). However, estimates of obesity prevalence among African children based on BMI-for-age should be approached with caution as noted above (Diouf et al. 2018).

1.9 Key behaviours influencing obesity and their health benefits to the early years

According to the Report of the Commission on Ending Childhood Obesity, key evidence indicates that physical activity, sedentary behaviours, and sleep are important factors affecting the risk of overweight and obesity in children under five years old (WHO, 2016). Understanding and addressing the behaviours that contribute to overweight and obesity in the early years is therefore critical. These behaviours are not only important for healthy growth and development but also significantly influence long-term health outcomes and the likelihood of developing NCDs, such as obesity (WHO, 2019). However, much of the available evidence examining these associations has been conducted in HICs, with comparatively limited research in LMICS.

This gap in evidence highlights the need for further research to understand whether the relationships observed in HICs are applicable to LMICs contexts, where social, environmental, and cultural factors influencing movement behaviours may differ substantially (Rollo et al.,2020).

Evidence from LMICs is emerging but remains inconsistent and context specific. For example, a study conducted in China by Guan et al. (2020) reported that children aged 4.1–6.3 years who did not meet the screen time guideline were at higher risk of overweight and obesity; however, non-compliance with physical activity or sleep guidelines, as well as complying with all combined guidelines, was not significantly associated with overweight or obesity.

Another study conducted in Mongolia among children aged 3 to 4 years found that the composition of movement behaviours, was significantly associated with motor skill outcomes, with the exception of functional mobility (Byambaa et al.,2024). Greater time spent in sleep relative to other behaviours was positively associated with postural steadiness. In contrast, longer durations of light physical activity relative to other behaviours were associated with poorer performance in both lower and upper body strength tests. Conversely, longer durations of moderate-to-vigorous physical activity relative to other behaviours were associated with better performance in lower and upper body strength as well as dexterity tests.

Similarly, a study from Brazil by Lucena Martins et al. (2020) reported that meeting movement behaviour guidelines was associated with motor competence in children. Meeting the physical activity guideline was positively associated with locomotion skills and with ball skills in 3- and 4-year-olds, although this relationship became negative in 5-year-olds. Meeting the screen time guideline showed positive associations with locomotion and ball skills in 3-year-olds, whereas negative associations were observed in 4- and 5-year-olds. In addition, meeting the sleep guideline was consistently associated with better locomotion and ball skills, highlighting the importance of adequate sleep for motor development in early childhood.

Findings from high-income settings provide additional support for the importance of 24-hour movement behaviours in early childhood health. A systematic review by Poitras et al. (2017) revealed that higher levels of physical activity, especially MVPA, are linked to reduced body fat in young children. Similarly, Carson et al. (2016) found that children aged 0 to 4 who engaged in more physical activity were not only less prone to being overweight or obese but also experienced enhancements in motor skill development and psychosocial well-being.

The importance of physical activity extends beyond merely preventing obesity. Physical activity is widely recognised as a fundamental contributor to children's motor development, cardiovascular health, and emotional well-being (Timmons, Naylor, & Pfeiffer, 2012). Engaging in regular movement from an early age supports the development of fundamental motor skills, including balance, coordination, and agility, which are critical for later participation in sports and daily activities (Poitras et al., 2016; Carson et al., 2017). Furthermore, systematic reviews have indicated that children engaged in physical activities exhibit enhanced emotional regulation, increased self-esteem, and better social skills, underscoring the beneficial effects of movement on mental health. These findings are supported by more detailed evidence linking movement behaviours to a broad range of physical, mental, and social health outcomes (Lubans et al., 2016; Biddle et al., 2019).

Traditionally, research has emphasised structured physical activity, such as sports, physical education programmes, and organised exercise, as key drivers of children's physical health and skill development. However, emerging evidence suggests that unstructured play and light-intensity movement are useful for fostering lifelong physical activity habits and enhance creativity, problem solving skills, and peer interactions (Gray et al., 2015; Tremblay et al., 2017). Spontaneous activities such as running, climbing, jumping, and playing outdoors contribute significantly to the development of motor competence and cognitive flexibility while also promoting peer bonding and socialisation (Carson et al., 2017; Brussoni et al., 2015).

Engaging in sedentary activities has also been associated with increased risk of childhood obesity, particularly when it involves excessive use of screens. Carson et al. (2016) in their systematic review, revealed that high screen time in children under five years old was linked to higher levels of body fat, as well as poorer motor skills and diminished psychosocial health. Similarly, a 2019 review by Stiglic and Viner found consistent links between excessive screen time, especially watching television, and overweight or obesity in children.

Supporting this evidence, De Craemer et al. (2016) emphasised that early sedentary behaviours, particularly those involving screens, may lead to the development of obesogenic habits (e.g. snacking, exposure to food advertising, lack of sleep) that can continue into later childhood and adolescence. These findings highlight the importance of reducing screen-based sedentary activities in early childhood as part of efforts to prevent obesity.

In addition to its role in contributing to obesity, excessive sedentary behaviour, particularly prolonged screen time, has been consistently linked to a range of other adverse health outcomes in young children. Screen-based activities, including television viewing, mobile device use, and video gaming, have been associated with poorer cognitive development, increased risk of obesity, and reduced social interaction (LeBlanc et al., 2017; Oswald et al., 2020). A growing body of evidence indicates that high screen exposure during early childhood can lead to delayed language acquisition, impaired executive function, and lower academic performance (Madigan et al., 2019; Domingues-Montanari, 2017). Additionally, excessive screen time was associated with increased sedentary behaviour, higher body fat percentages, and an elevated risk of metabolic disorders (Carson et al., 2016; Sampasa-Kanyinga et al., 2020).

It is important to note that not all sedentary behaviours are negative to child development. Activities such as reading, storytelling, and interactive educational play have been shown to enhance cognitive function, improve literacy skills, and foster creativity (Carson et al., 2017; Pillon et al., 2021). A recent systematic review and meta-analysis conducted by Mallawaarachchi et al. (2024) found that for children under the age of six, engaging with screen media alongside or with the participation of another person is positively linked to cognitive outcomes. This co-use not only promotes interaction and vocabulary growth but also provides opportunities for developing cognitive skills through caregiver assistance. Several studies have also indicated that high-quality, structured sedentary activities, especially those that involve parent child interaction or educational content, can have a beneficial impact on early learning and social emotional development (Nathanson et al., 2014; Barr & Linebarger, 2017).

However, it is important to note that these activities may adversely impact the time allocated to behaviours that have beneficial effects on health and development, such as active play and sleep. In particular, passive screen-based activities tend to inhibit physical activity, unstructured play, and meaningful social interaction (Hinkley et al., 2014; Tremblay et al., 2017).

Contradictory evidence further complicates the relationship between sedentary behaviour and child development. One study reported that children aged 4 to 6 years who scored higher on measures of hyperactivity and inattention spent less time in sedentary activities, suggesting

that less sedentary time may not always indicate better health if it reflects behavioural or regulatory challenges (Ebenegger et al., 2012).

These inconsistencies highlight the importance of differentiating between various types of sedentary behaviours, where possible. While screen-based activities are often linked to adverse health outcomes, other sedentary behaviours, such as reading or quiet play, may have neutral or even beneficial effects on child development. Furthermore, many studies rely on parent reported data, which may be subject to recall bias or combine all sedentary time, potentially masking the effects of specific behaviours.

In conclusion, although substantial evidence supports the association between excessive screen time and adverse health outcomes in early childhood, the overall relationship between sedentary behaviour (defined as sitting or lying down) and health outcomes remains unclear. High-quality research employing objective measurement tools, such as accelerometers, is needed to understand these associations better. Nevertheless, capturing specific types of sedentary behaviour, such as screen time, remains methodologically challenging (Carson et al., 2016; Cliff et al., 2016). Such studies should also differentiate between various types of sedentary activities and consider the influence of other movement behaviours, such as physical activity and sleep, to provide a more comprehensive understanding of how sedentary time impacts health.

Sleep is another crucial behaviour that influences childhood obesity. Extensive research has consistently demonstrated a strong association between both the duration and quality of sleep and the risk of obesity across all age groups, including young children, older children, adolescents, and adults. Numerous studies have highlighted that inadequate sleep during the early years is associated with increased body fat and a higher body mass index (BMI). For instance, Magee et al. (2017) and Chaput et al. (2016) consistently reported that shorter sleep durations in young children were associated with higher BMI, increased fat accumulation, and a greater risk of obesity. These findings highlight the importance of ensuring adequate and quality sleep in preventing obesity during the early years of development. Recent studies suggest that following several parts of the 24-hour movement guidelines can provide stronger protection against childhood obesity. Leppänen et al. (2019) found that children who met more of these guidelines were less likely to develop overweight or obesity. Meeting recommendations for physical activity and sleep appeared to play a key role in supporting a healthy weight among young children. Similarly, Chaput et al. (2017) reported that young

children who achieved all three guidelines being physically active, limiting sedentary behaviour, and getting enough sleep had a lower risk of obesity.

These findings highlight the value of considering the full 24-hour day when promoting health in early childhood.

While the association between sleep and obesity is well documented, it is important to acknowledge that sleep also affects other significant health trajectories in children. For instance, adequate sleep is a fundamental aspect of health, playing a fundamental role in cognitive function, mood regulation, and metabolic processes (Liu et al., 2024; Chaput et al., 2016). In early childhood, sleep is vital for memory consolidation, emotional stability, and overall physiological development, influencing both immediate well-being and long-term health outcomes (Lokhandwala et al., 2012). Research has shown that insufficient or poor-quality sleep among young children is linked to a range of negative health and developmental consequences, including behavioural difficulties, attention deficits, weakened immune function, and increased risks of obesity and metabolic disorders (Chaput et al., 2016; Hale & Guan, 2015). For example, a comprehensive systematic review by Chaput et al. (2017) found that in 20 out of 31 studies involving children aged 0 to 4 years, shorter sleep duration was associated with higher levels of body fat. These findings suggest a potential dose response relationship, where insufficient sleep contributes to excessive weight gain. This may occur through hormonal changes, increased appetite, greater exposure to food advertising, and reduced physical activity due to displacement or fatigue.

Moreover, sleep deprivation in children and adolescents has been consistently linked to increased food consumption, particularly unhealthy, energy dense foods, which exacerbates the risk of obesity (Calcaterra et al., 2023). Research indicates that insufficient sleep disrupts the hormonal regulation of appetite, leading to behaviours such as increased snacking and a preference for high calorie foods. Importantly, the relationship between sleep duration and dietary behaviour is bidirectional. While inadequate sleep influences food choices, poor dietary habits (e.g., high sugar or fat intake) can also disrupt sleep quality and duration in children (Calcaterra et al., 2023). This reciprocal relationship highlights the complex interplay between sleep and nutrition.

Despite the growing body of evidence, significant gaps remain in understanding the full impact of sleep on child health. Many studies rely on subjective sleep measures or fail to account for confounders, and the variability in findings further complicates the picture.

To better understand the role of sleep in childhood health, there is a pressing need for high-quality, longitudinal research that employs objective sleep measurements when feasible, considering confounding factors and exploring dose response relationships. Such research is useful for informing evidence-based sleep recommendations tailored to the needs of young children, guiding interventions aimed at improving sleep habits and overall health during this critical developmental stage.

1.10 Conceptualisation of 24-hour movement behaviours

The concept of 24-hour movement behaviours has emerged as a new paradigm in health research, integrating physical activity, sedentary behaviour, and sleep into a cohesive framework that recognises their joint influence on child's health and development (Tremblay et al., 2016; Tremblay, 2020). Rather than examining these behaviours in isolation, the 24-hour movement approach considers the interconnected and interdependent nature of these behaviours within a fixed daily cycle (Chaput et al., 2017; Pedišić, Dumuid, & Olds, 2017).

Figure 1-3 presents the conceptual framework of movement behaviours across a 24-hour period. Within this integrated framework, activities are classified according to intensity, namely light-intensity physical activity (LPA), moderate-intensity physical activity (MPA), and vigorous-intensity physical activity (VPA), as well as sedentary behaviour and sleep (Rao et al., 2016). The distinction between these behaviours can be further defined in terms of energy expenditure. Sedentary behaviours are characterised by activities that require ≤ 1.5 metabolic equivalents (METs), while physical activity is defined as any movement requiring >1.5 METs (Pedišić et al., 2017). Understanding these distinctions is crucial as each behaviour uniquely contributes to health outcomes in young children (Chaput et al., 2017).

The conceptual framework of movement behaviours.



Figure 1-3: Conceptual model of movement behaviours based on a 24-hour period. Redrawn from Tremblay, M.S., Aubert, S., Barnes, J.D., et al. (2017). Sedentary Behaviour Research Network (SBRN) – Terminology Consensus Project process and outcome. International Journal of Behavioural Nutrition and Physical Activity, 14, 75. <https://doi.org/10.1186/s12966-017-0525-8>.

In response to the growing evidence supporting an integrated approach to movement behaviours, several countries have developed their national 24-hour movement guidelines for young children. Among the pioneers in this area, Canada, Australia, New Zealand and South Africa have launched evidence-based guidelines aimed at promoting optimal physical activity, reducing sedentary time, and ensuring adequate sleep in early childhood (Tremblay et al., 2016; Australian Government Department of Health, 2019; New Zealand Ministry of Health 2017; Draper et., 2020). These recommendations align with the WHO's guidelines on physical activity, sedentary behaviour, and sleep for children under five years of age (WHO, 2019), and the WHO guidelines were based on an updated review and appraisal of the literature used to produce the Canadian and Australian 2017 guidelines. According to the WHO 2019 guidelines, children aged 3 to 4 years should engage in at least 180 minutes of total physical activity per day, including at least 60 minutes of MVPA, while also ensuring sufficient sleep (10 to 13 hours per night) and limiting sedentary screen time to one hour or less (WHO, 2019). These guidelines aim to promote a healthy balance of movement behaviours throughout the day, recognising that the composition of these behaviours is related to various health indicators as shown by systematic reviews used to develop the guidelines (Lemos et al., 2021; Tremblay, 2020).

Substantial evidence supports the importance of these behaviours in combination for promoting childhood health. Studies consistently demonstrate positive associations between compliance with these integrated guidelines and improved health outcomes. Recent systematic reviews by Kracht et al. (2024) and Silva et al. (2025) provide robust evidence reinforcing these findings. Kracht et al. reported consistent links between higher levels of MVPA, compliance with all three components of the 24-hour movement guidelines, and a range of beneficial health outcomes. Similarly, Silva et al. found that healthier combinations of movement behaviours, characterised by reduced sedentary behaviour, increased physical activity, and sufficient sleep, were consistently associated with enhanced cognitive health, exposure to pollution, and the use of eHealth interventions. Collectively, these findings underscore the importance of promoting a balanced and integrated approach to daily movement behaviours to support optimal growth, development, and well-being in children and adolescents. Additionally, evidence underscores the reciprocal influence among these behaviours; increasing physical activity can enhance sleep quality and reduce sedentary

behaviour, whereas excessive screen time negatively impacts sleep duration and quality (Hale & Guan, 2015; Carter et al., 2016).

Despite the establishment of these guidelines and the well evidence-based benefits supporting them, compliance remains alarmingly low worldwide. A systematic review conducted by Rollo et al. (2020) investigated compliance among children and adolescents, consistently identifying low compliance across various age groups. Their analysis indicated a low overall compliance, particularly among children in the 3 to 5 year age group, with only 11% meeting recommendations for TPA, MVPA, screen time, and sleep duration combined, while 9% did not meet any of the guidelines. A recent multinational cross-sectional study conducted by Chong et al. (2024) presented results from a pooled and reanalysed accelerometry dataset involving 7,017 children aged between 3.0 and 4.9 years from 33 different countries. The research also incorporated parent proxy reports on screen time and sleep, with data gathered from 2008 to 2022. The overall prevalence of children complying with all three components of the 24-hour movement guidelines (physical activity, screen time, and sleep) was 14% (95% CI: 10–21%). The physical activity guideline in this study was defined as achieving a minimum of 180 minutes of total physical activity per day, of which 60 minutes should be of MVPA. Notably, the prevalence of compliance with all three guidelines did not show systematic variation based on the income level of the countries, indicating a global challenge in meeting 24-hour movement recommendations. This lack of compliance is particularly concerning given that movement behaviours established in early childhood can significantly influence both short and long-term health as noted above. Addressing this low compliance is critical given the lasting impact of early life movement behaviours on long-term health outcomes. Research emphasises the need for integrated intervention strategies that simultaneously address physical activity, sedentary time, and sleep (Carson et al., 2017; Kuzik et al., 2017). Additionally, identifying critical developmental periods for targeted interventions can further enhance their effectiveness (Telama et al., 2014; Timmons et al., 2007).

To effectively assess the integrated nature of these behaviours, researchers increasingly utilise compositional data analysis (CoDA), which accounts for the interdependency of movement behaviours (Dumuid et al., 2018; Fairclough et al., 2021). CoDA methods provide insights into how changes in one behaviour (e.g., shifting from sedentary activities to physical activity) impact the relative distribution and subsequent health outcomes, thereby offering a comprehensive perspective on children's health (Dumuid et al., 2019).

Studies using CoDA have demonstrated significant health benefits from reallocating sedentary time to physical activity, including improved motor skills, cognitive function, and obesity prevention (Dumuid et al., 2018; Bazerra et al., 2020).

Conversely, even high levels of physical activity may not mitigate the adverse effects of inadequate sleep on cognitive and emotional health, further illustrating the necessity of maintaining balanced movement behaviours (Chaput et al., 2016; Kuzik et al., 2017).

Overall, the conceptualisation of 24-hour movement behaviours as endorsed by WHO (2019) highlights the importance of considering physical activity, sedentary behaviour, and sleep collectively. This holistic approach aligns with contemporary scientific understanding of the interrelated nature of movement behaviours across a 24-hour period. It also provides a practical framework for promoting optimal health and developmental outcomes in early childhood, highlighting the need for integrated guidelines and targeted, evidence-based interventions (WHO,2019; Tremblay et al., 2016).

1.11 Associations between meeting versus not meeting 24-hour movement behaviour guidelines and health outcomes in children aged 3 to 4 years

Numerous studies have examined compliance with the 24-hour movement guidelines and association with various health indicators during early childhood (Chia et al., 2020; Berglind et al., 2018; Meredith et al.,2019; Leppänen et al., 2019). Despite the growing body of literature in this area, the evidence remains somewhat inconsistent and inconclusive regarding whether young children who comply with one or more components of the guidelines consistently show better physical, cognitive, or emotional health compared to their non compliant peers (Guan et al., 2020; Leppänen et al., 2019; Santos et al., 2017). Some studies have identified a significant positive association between compliance with guidelines and improved health outcomes, while others have reported weak or no association, as shown in **table 1–1**.

Table 1-1: Evidence: Summary of studies examining associations between combinations of 24-hour movement behaviours and health outcomes in children aged 0–4 years, based on evidence from the WHO 2019 guidelines, the Canadian 24-hour movement guidelines, and the Australian 24-hour movement guidelines for the early years.

Author/ year design/population	Measures of PA/ST and sleep	Health-related indicator	Main results
Chaput et al., 2017 ^a Cross – Sectional study design Mean age: 3.5 years (N=803)	PA was measured by Actical accelerometers ST and sleep were measured by Parent's in -home interview	BMI z-score, risk of being overweight, or obesity	No associations
Guan et al., 2020 ^b Cross-sectional design, Children aged 4.1-6.3 (N=254)	PA was measured by Actigraph GT9X accelerometers. ST was measured by Parent report questionnaire. Sleep was measured by Actigraph GT9X, matched with activity log	Odds ratios for being overweight and obese	Children who did not meet the ST guideline were at higher risk for overweight and obesity
Kracht et al., 2019 ^c Cross-sectional design Children aged 3 to 4 years (N=107)	PA was measured by Actigraph GT3X+ accelerometers. ST was measured by Parent report questionnaire.	Age and sex adjusted BMI percentile, weight status	No associations

^a Australian guideline

^b WHO guidelines

^c Canadian guidelines

	Sleep was measured by Actigraph GT3X+		
Leppänen et al., 2019 ^c Cross-sectional Children aged 3 to 4 years (N=778)	PA was measured by Actigraph wGT3X-BT, ST was measured by Parent report diary (translated from 7-day sedentary behaviour diary and modified) Sleep was measured by parent report diary (translated from 7-day sedentary behaviour diary and modified)	Waist circumferences Body mass index (BMI)	Meeting guidelines separately for PA or Sleep, or for both, were associated with lower waist circumferences Meeting guidelines for Sleep or for both PA and Sleep were associated with lower BMI
Leppänen et al., 2019 ^c Cross-sectional Children aged 3 to 4 years (N=778)	PA was measured by Actigraph wGT3X-BT, ST was measured by Parent report diary (translated from 7-day sedentary behaviour diary and modified) Sleep was measured by parent report diary (translated from 7-day sedentary behaviour diary and modified)	Waist circumferences Body mass index (BMI)	Meeting guidelines separately for PA or Sleep, or for both, were associated with lower waist circumferences Meeting guidelines for Sleep or for both PA and Sleep were associated with lower BMI
Meredith-Jones et al., 2019 ^c Longitudinal study design at 1,2 and 5 years (N=547)	PA was measured by Actical accelerometers ST was measured by Parent report questionnaire Sleep was measured by Actical	Absolute BMI z-score, body composition (percentage fat, fat mass index, fat-free mass index)	No associations

Chia et al., 2020 ^b Cross-sectional design, Children under 5 years (N=2384)	PA, ST and Sleep were measured by Parent report online survey (SMALLQ®)	Quality of life: The Pediatric Quality of Life 4.0 Inventory score	Significant differences were detected in the health-related quality of life of preschool children, with those meeting all WHO guidelines reporting higher scores compared to those meeting none or only 1–2 guidelines
Cliff et al., 2017 ^a Cross-sectional study design Children with mean age = 4.2 ± 0.6 years (N=248)	PA was measured by Actigraph GT3X+ ST and sleep were measure by Parent report questionnaire	Social-cognitive development: TEC score, ToM score	Children meeting the Sleep guideline performed better on TEC. Children meeting the PA and Sleep or ST and Sleep guidelines also performed better on TEC and ToM, respectively. Meeting all three guidelines was associated with better ToM performance.
McNeill et al., 2020 ^a Longitudinal study design Early years children (N=247)	PA was measured by Actigraph GT3X+ ST and sleep were measured by Parent report questionnaire	Psychological difficulties: Strengths and Difficulties Questionnaire	No cross-sectional or longitudinal associations were observed between meeting guidelines and psychosocial health.
Kracht et al., 2020 ^b Longitudinal study design Children aged 3 to 4 years (N=107)	PA and sleep were measured by Actigraph GT3X+ ST was measured by Parent report questionnaire	Fundamental motor skills: Test of Gross Motor Development Third edition	Meeting the ST guideline at baseline was associated with higher total fundamental motor skills at one-year follow-up. Compared to meeting one guideline, meeting all three guidelines at baseline was associated with higher total fundamental motor skill at one-year follow-up.
Byambaa et al., 2024 ^b Cross-sectional study Children aged 3 to 4 years (N=100)	PA was measured by Actigraph WGT3x accelerometers ST and sleep were measured by Parent report- questionnaire	Fundamental motor skills	Positive association between adequate sleep and motor development

Lucena Martins et al., 2020 ^b Cross-sectional design, Children with means age = 3.97 ± 0.80 (N=212)	PA was measured by Actigraph WGT3 X ST and sleep were measured by Parent report questionnaire	Fundamental motor skills: Test of Gross Motor Development Second Edition	Meeting the PA guideline was positively associated with locomotion skills. Meeting the PA guideline was positively associated with ball skills in 3 and 4 year olds, while the association became negative in 5 year olds. Meeting the ST guideline was positively associated with locomotion and ball skills in 3 year olds, while the association was negative for 4 and 5 year olds. Meeting the Sleep guideline was associated with locomotion and 2 ball skills.
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Abbreviations: PA- Physical activity, ST-Screen time, SB- Sedentary behaviour, BMI- Body mass index, N=number

Feng et al. (2021), in a systematic review and meta-analysis, examined the associations between compliance with the 24-hour movement behaviour guidelines and various health indicators among children under five years of age. The review found no statistically significant associations between compliance with the guidelines and body fatness outcomes, such as BMI z-scores. However, the authors highlighted the limitations of relying solely on BMI and related indices in early childhood, emphasising the need for more precise and sensitive measures of adiposity and robust longitudinal research designs.

Notably, the review identified a consistent dose response relationship, whereby compliance with a greater number of guideline components was associated with enhanced psychosocial well-being, suggesting potential benefits for emotional and social development during the formative early years. In contrast, evidence linking compliance with the guidelines to motor and cognitive development outcomes was either mixed or insufficient, underscoring the need for further targeted investigation. Moreover, the predominance of cross-sectional observational studies in the literature limits the ability to infer causality, reinforcing the importance of well designed longitudinal and experimental studies to clarify these relationships.

Evidence regarding the relationship between compliance with the 24-hour movement guidelines and body fat outcomes in early childhood remains inconsistent. For example, a study involving Canadian children aged 3 to 4 years found no significant associations between compliance with the individual or combined recommendations for physical activity, screen time, and sleep duration and measures of body fat (Chaput et al., 2017). In contrast, a study conducted among Japanese children aged 3 to 5 years reported that those not meeting all three components of the guidelines (physical activity, sedentary behaviour, and sleep) had significantly higher odds of having overweight or obesity compared to those meeting all recommendations (Kim et al., 2020). Similarly, a recent European longitudinal study observed that children aged 4 to 6 years who did not comply with the integrated guidelines experienced a small but statistically significant increase in BMI z-scores over one year compared with those who met all recommendations, but this increase was not considered clinically meaningful (DeCraemer et al., 2024).

These discrepancies underscore the necessity for further research across diverse populations and study designs to elucidate the complex relationship between movement behaviours and body fat in early childhood.

Given this mixed evidence, it is essential to investigate these relationships further. Therefore, this section aims to examine the associations between time spent in movement behaviours and health outcomes in young children.

1.11.1 Physical activity and health outcomes

As noted above, a systematic review conducted by Carson et al. (2017) synthesised evidence regarding the associations between physical activity and various health indicators in children aged 0 to 4 years. The review identified several consistent findings across studies: physical activity in early childhood was positively associated with improved motor development, cognitive development, psychosocial well-being, and cardiometabolic health. Notably, higher intensity physical activity including TPA, MVPA, and VPA was more consistently associated with favourable health outcomes compared to light or moderate intensity activity alone. Furthermore, the review identified a dose response relationship, wherein greater volumes of physical activity were generally linked to more substantial health benefits across studies, underscoring the importance of promoting more physical activity from an early age. The review by Carson et al. (2017) provided a foundational evidence base for the development of the World Health Organization's guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age (WHO, 2019). The findings of this review were revised and broadened later to include new empirical evidence on which to base the WHO 2019 guidelines. This ensured that the guidelines were based on the most up-to-date and comprehensive body of global evidence available.

Similarly, another systematic review by Pate et al. (2019) explored the link between physical activity and health outcomes in children younger than six. The review offered strong evidence showing that increased physical activity is associated with better bone health and a reduced risk of excessive weight gain in children aged 3 to 6 years. This finding underscores the importance of encouraging physical activity during early childhood as a foundation for long-term health. However, the review by Pate et al identified a lack of sufficient evidence to draw definitive conclusions regarding the effects of physical activity on cardiometabolic health and cognitive development within this age group, thereby highlighting critical gaps in the existing literature and the necessity for further research in these domains. Although higher levels of physical activity were generally associated with more favourable health outcomes, the review was unable to establish clear dose response relationships.

This suggests that more precise investigations are required to ascertain the optimal type, intensity, and duration of physical activity necessary to support health in young children.

1.11.2 Sedentary behaviour and health outcomes

Sedentary behaviours in young children aged 3 to 4 years have been associated with various health outcomes. Studies have shown that higher levels of sedentary time, particularly screen time, are linked to adverse health effects in this age group. A systematic review by Poitras et al. (2017) examined the associations between sedentary behaviours and health indicators in children aged 0 to 4 years, with key findings highlighting the importance of the type as well as the total amount of sedentary behaviour. While overall sedentary time appeared to have minimal impact on health outcomes, screen-based sedentary behaviours such as television viewing were consistently associated with unfavourable or null effects, particularly body fat, motor and cognitive development, and psychosocial health. In contrast, non-screen sedentary activities, such as reading and storytelling, were linked to favourable or neutral outcomes, especially for cognitive development. These findings suggest that although some sedentary time is standard and potentially beneficial part of early childhood, the quality and context of that time are critical. The findings provided evidence-based on current public health recommendations advocating for limiting screen time in young children and encouraging engagement in interactive, non-screen activities to promote optimal developmental outcomes. However, the review also noted a lack of high-quality evidence, underscoring the need for further research to clarify the specific health impacts and appropriate thresholds of different types of sedentary behaviour in this age group.

In their systematic review, LeBlanc et al. (2012) explored the associations between sedentary behaviours and health outcomes in children aged 0 to 4 years. The main findings revealed that increased television watching is associated with negative effects on body fat, psychosocial health, and cognitive development. Notably, there was no evidence to suggest that television viewing benefits psychosocial or cognitive development, rather, several studies showed a dose response relationship, where more television exposure correlated with worse outcomes in these areas. The review found low to moderate quality evidence supporting these associations, indicating that while the findings are not conclusive, they are significant enough to warrant concern and further investigation. These findings have crucial implications as the foundational evidence informing public health guidelines, particularly those targeting screen time and sedentary behaviour in early childhood (WHO, 2019).

They also contributed to the formulation of the WHO's 2019 guidelines. Specifically, reducing television viewing has been identified as a key strategy to promote healthier developmental trajectories in young children. The authors also highlight the need for more high-quality research that uses direct measures of sedentary behaviours beyond television viewing to understand these relationships better.

1.11.3 Sleep and health outcomes

In a systematic review, Chaput et al. (2017) explored the associations between sleep duration and various health indicators in children aged 0 to 4 years. The review found that shorter sleep duration was generally linked to higher body fat, poorer emotional regulation, impaired growth, increased screen time, and a greater risk of injuries. While these findings align with and have informed existing recommendations for sleep duration in young children, the authors caution that the current evidence base remains limited in both quantity and quality. The quality of evidence across studies varied from very low to high, depending on the health outcome and methodological design.

The review further highlights that sleep health should not be defined solely by duration. Other dimensions like sleep quality, consistency, and timing are important for ensuring optimal development. Despite the clear associations identified, several research gaps persist. Notably, there is a paucity of studies addressing cardiometabolic health outcomes in this age group, and objective measures of sleep, such as actigraphy, are infrequently employed. To enhance the evidence base and inform more comprehensive sleep guidelines, the authors advocate for more rigorous research designs, including longitudinal studies, dose response analyses, and intervention trials. Overall, the review underscores the importance of adequate, high-quality sleep in early childhood and the necessity for further research to guide evidence-based recommendations and interventions.

Building on these findings, Matricciani et al. (2019) conducted a comprehensive meta-review that synthesised evidence from multiple systematic reviews to assess the relationship between sleep and various health outcomes in children. This review, which focused on children and adolescents under 19, underscored the vital role of sleep in health across cognitive, psychosocial, and cardiometabolic domains. It consistently found associations between sleep duration with increased body fat and emotional outcomes, highlighting the importance of adequate sleep for maintaining a healthy weight and emotional well-being.

However, the authors noted that other dimensions of sleep, such as quality, timing, and variability, remain under researched, with limited evidence on their associations with outcomes such as blood lipid profiles and glycaemic control. Notably, the review found that evidence linking sleep to metabolic syndrome in children was weak and inconsistent, highlighting the need for more robust and targeted investigations in this area. Additionally, several methodological limitations were identified in the existing literature, including a heavy reliance on self-reported sleep measures and the predominance of cross-sectional study designs. These limitations constrain the ability to infer causality, thereby necessitating the use of objective sleep measures and longitudinal research designs in future studies. The review further advocates for a multidimensional approach to studying sleep, ideally encompassing not only duration but also quality, timing, and regularity, and for considering sleep as an integral component of the 24-hour activity cycle.

Healthcare providers in LMICs, including SSA, should, ideally, prioritise screening for sleep problems and provide parent education on the importance of adequate sleep for child health and development (Bonuck et al., 2022). Such strategies should be adapted to the cultural, resource, and healthcare contexts of LMIC and SSA settings to ensure feasibility and effectiveness.

1.11.4 Integration of 24-hour movement behaviours and health outcomes

There is an increasing body of evidence indicating that an integrated approach to movement behaviours encompassing physical activity, sedentary behaviour, and sleep may be fundamental for fostering optimal health and development in early childhood (Tremblay et al., Chaput et al., 2017; Okely et al., 2017).

Emerging evidence suggests that compliance with two or more components of the 24-hour movement behaviour guidelines is associated with a wide range of positive health outcomes in children aged 3 to 4 years. These include enhanced physical fitness, improved emotional regulation, better psychosocial well-being, and optimal cognitive and language development (Tremblay et al., 2016; Chaput et al., 2017; Okely et al., 2017).

In alignment with these findings, a systematic review conducted by Kuzik et al. (2017) examined the associations between combinations of movement behaviours and health outcomes in children aged 1 month to 4.99 years.

The review indicated that optimal combinations of physical activity, restricted sedentary behaviour, and sufficient sleep were generally linked to positive outcomes, particularly in motor development, physical fitness, and, in some cases, body fat.

These findings underscore the significance of a 24-hour movement behaviour framework during early childhood. Nonetheless, the overall quality of evidence was assessed as low to very low, primarily due to methodological limitations present in the included studies.

1.12 Framework for movement behaviour research

As mentioned earlier in Section 1.7, the Behavioural Epidemiology Framework (BEF) (Sallis et al., 2000), provides a systematic method for understanding and modifying health-related behaviours by exploring their determinants, measurement, and connections to health outcomes. This framework serves as the theoretical foundation of the current thesis, which investigates the extent to which young children's movement behaviours align with the WHO 24-hour movement behaviour guidelines and links to future research on how that might be used to inform interventions.

The 24-hour movement behaviour guidelines have been developed as a fundamental focus in public health research, given their potential to enhance optimal health across an individual's lifespan (Tremblay et al., 2016). The guidelines emphasise the importance of increasing physical activity, reducing sedentary behaviours, and ensuring sufficient and high-quality sleep within daily routines. By exploring the health implications of these behaviours, researchers can gain insights into how they interact to promote health outcomes in various age groups.

The BEF is widely used in public health and epidemiology to examine behavioural risk factors associated with diseases and to guide evidence-based interventions (Bauman et al., 2012). For instance, research employing this framework has successfully identified key determinants of physical activity in some populations, such as social support, the availability of recreational areas, and neighbourhood walkability. These findings have informed the development of targeted interventions, including community walking programmes, school-based physical activity initiatives, and workplace wellness schemes (Owen et al., 2011). Further, this framework has played a crucial role in shaping policies aimed at obesity prevention and the control of non-communicable diseases (Hallal et al., 2012).

Thus, the BEF not only enhances our understanding of health behaviours but should also ensure that interventions and policies are grounded in evidence, are sustainable, and have a substantial impact (Sallis et al., 2000).

The BEF consists of five distinct phases, summarised below, each of which is thought to be essential for developing effective health-promotion strategies (Sallis & Owen, 1999). This model is particularly well suited to the study of 24-hour movement behaviours, as it offers an evidence-based framework for examining health-related behaviours, with the ultimate aim of informing and guiding movement behaviour interventions at both individual and population levels (Sallis, Owen, & Fotheringham, 2000).

Stage 1: Establishing the health effects of movement behaviours

This first stage of the framework involves epidemiological studies that investigate the association between movement behaviours (physical activity, sedentary behaviours, and sleep) and various health outcomes. These studies should provide evidence on how movement behaviours affect children's health. For example, numerous studies as summarised above have repeatedly demonstrated that increased physical inactivity, prolonged sedentary behaviours, and insufficient sleep, in children aged 3 to 4 years are consistently linked to various adverse negative health outcomes.

Stage 2: Developing reliable methods for measuring movement behaviours

Accurate and reliable measurement methods play an important role in identifying the relationships between movement behaviours and health outcomes. In the second phase of the BEF, the focus is on developing and validating tools that can consistently assess physical activity, sedentary behaviour, and sleep. This stage is critical because the quality and reliability of measurement tools directly affect the credibility and applicability of research findings. High-quality measurement instruments can, therefore, provide robust data, supporting both researchers and policymakers in making informed decisions.

Aligned with the measurement phase of the BEF (**Figure 1-4**), the SUNRISE Study protocol (Okely et al., 2021) was developed, marking a significant methodological advancement. The protocol integrated objective measures, such as accelerometers, and subjective measures, including parent-reported questionnaires, to provide comprehensive assessment of 24-hour movement behaviours among children aged 3–4 years.

The use of standardised procedures strengthens methodological rigour, enables cross-country comparisons, and improves the quality of global surveillance data.

While a standardised protocol is important, the feasibility of that protocol could not be guaranteed and so the SUNRISE Study protocol (Okely et al., 2021) required some feasibility testing in many different countries. Study 2 (Chapter 3) of the current thesis implemented the SUNRISE protocol in the Tanzanian context to evaluate its feasibility and applicability. This application contributes context-specific evidence to the measurement phase of the BEF and advances the assessment of 24-hour movement behaviours in early childhood within a low-income setting.

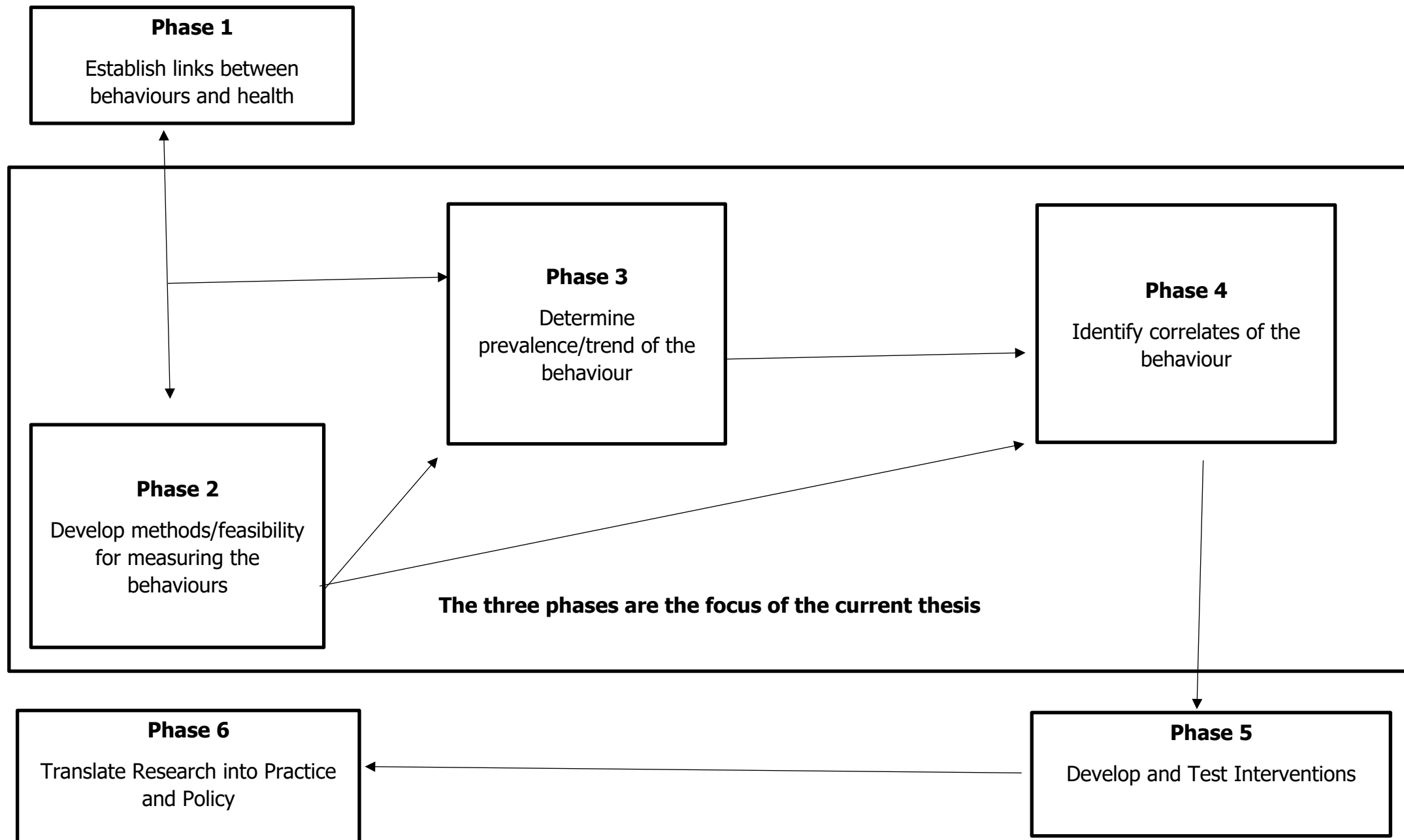


Figure 1-4: Behaviour Epidemiological Framework- Applied to the current thesis on movement behaviours in sub-Saharan Africa

Stage 3: Identifying factors that influence health behaviours

Following the establishment of the foundational stages (Stages 1 and 2) of the BEF, Stage 3 emphasises prevalence and correlates studies. These studies aim to determine the proportion of a population affected by specific health conditions or behaviours at a given point in time (Fortin et al., 2012). Prevalence studies often identify correlates e.g. factors that influence compliance with movement behaviour guidelines. These studies form the basis for determining whether and how to proceed through the subsequent stages of the BEF. For instance, if prevalence data highlight significant non-compliance with movement behaviour guidelines, this strongly supports further research to examine correlates of compliance, develop interventions, and evaluate their effectiveness. Conversely, if prevalence rates are not of significant concern, this may indicate that additional research or intervention efforts may not be a current priority. Thus, prevalence studies play both descriptive and strategic roles, influencing public health research directions and policy-making initiatives.

Consistent with the correlates phase of the BEF, identifying determinants of movement behaviours is essential for informing targeted strategies that address context-specific barriers and facilitators across populations. Within this framework, study 3 (Chapter 4) of the thesis examined a range of potential correlates including urban versus rural differences in compliance with the 24-hour movement behaviour guidelines among children aged 3 to 4. Drawing on data from the SUNRISE pilot studies conducted across 10 LMICs, the study investigated whether environmental context (urban versus rural settings) was associated with variations in compliance with the guidelines. By situating this analysis within the BEF, the study contributes to the evidence base required to inform contextually appropriate interventions and policies in future.

In this thesis, stages 4 and 5 of the Behavioural Epidemiology Framework were not implemented. However, these stages may be followed in the future if robust evidence emerges from stages 1 to 3, supporting the development and evaluation of interventions in stage 4. Should these interventions prove effective in stage 4, they can be scaled up and translated into population-wide initiatives in stage 5.

1.13 Potential correlates of movement behaviours in children aged 3 to 4 years

In addition to the BEF, the current thesis is conceptually informed by the SEM, with each framework playing distinct yet complementary roles. The BEF provides the overarching structure for the research, guiding the examination of the prevalence, measurement, and correlates of 24-hour movement behaviours, as well as their implications for intervention and policy (Bauman et al., 2016; Sallies et al., 2000). Conversely, the SEM offers a theoretical lens through which the multilevel influences on these behaviours can be comprehended (Daniel Stokols, 1996). Specifically, it aids in the interpretation of correlates identified within the BEF by situating them across interacting layers of a child's environment, including individual, interpersonal, organizational, community, and policy levels. In doing so, the SEM enhances the explanatory depth of the correlates examined in the current thesis. Furthermore, as the research progresses towards informing interventions, the SEM underscores the importance of targeting multiple levels of influence rather than focusing solely on the individual. **(Figure 1-5).**

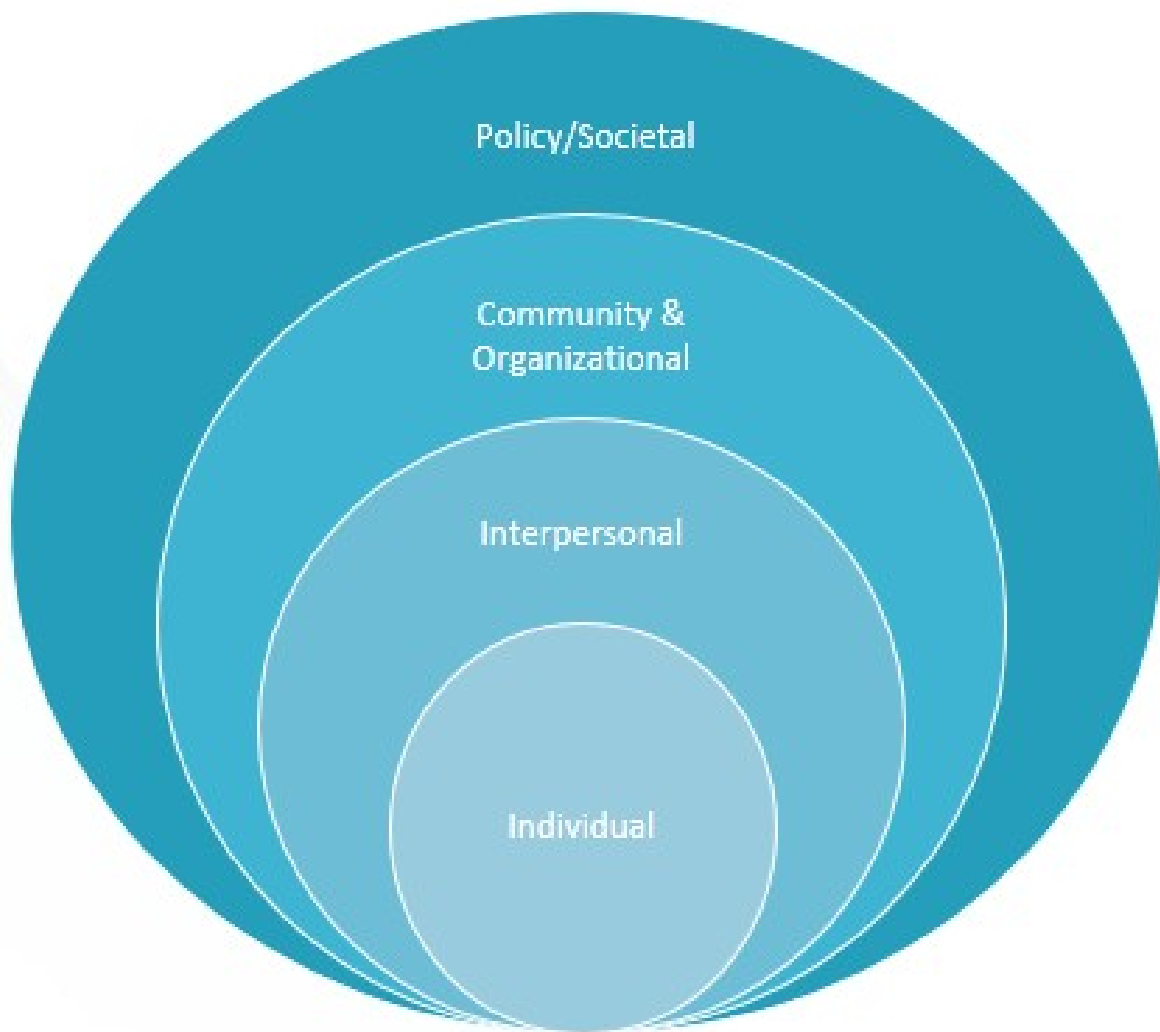


Figure 1-4: Social-Ecological Model Source: Adapted from Bronfenbrenner, U. (1979). The ecology of human development. Cambridge, MA: Harvard University Press.

Interventions based on the SEM approach ideally target multiple levels simultaneously, reflecting the complexity of behaviour-change processes. For example, interventions aimed at reducing sedentary behaviours among children often use strategies that address individual behaviours, social relationships, organisational environments, and broader community contexts concurrently, thereby increasing the likelihood of achieving sustained behaviour change (Cholley-Gomez et al., 2023). Similarly, school-based interventions that combine teacher-led physical activity promotion, parental involvement, and supportive environmental modifications (e.g., improved access to playgrounds and enhanced walkability) tend to be more effective than single-component approaches focusing solely on the individual child (Van Sluijs et al., 2011).

At the intrapersonal level of the SEM, a child's biological, psychological, and behavioural characteristics are crucial in determining their movement behaviours. Factors such as age, sex, genetics, and activity preferences can significantly influence children's propensity to engage in physical activity, sedentary behaviours, and sleep duration (Carson et al., 2017). These intrapersonal determinants interact dynamically with environmental and social influences, affecting not only the frequency and type of movement behaviours but also long-term health outcomes.

Evidence suggests that age-related differences significantly impact movement behaviours. Younger children typically engage in higher levels of spontaneous active play, whereas older children are more likely to participate in structured physical activities or screen-based behaviours (Maitland et al., 2013).

Sex differences also influence movement behaviours. Arts et al. (2023) conducted a comprehensive umbrella review alongside international expert consultation to examine the correlates of physical activity in children aged 0 to 5 years. One key finding was that male sex was positively associated with higher levels of physical activity. This suggests that even in early childhood, sex differences in physical activity may already be emerging, potentially reflecting biological (sex) or environmental influences. This finding implies that interventions aimed at promoting physical activity should be sensitive to sex-specific needs and behaviours. Recognising that boys may naturally engage in more physical activity than girls at this age underscores the importance of creating equitable opportunities and supportive environments that encourage active play for all children, particularly for girls who may be less active.

Addressing these disparities early in life could help establish lifelong patterns of physical activity and reduce the risk of developing sedentary lifestyles later in childhood. These differences are influenced by both biological predispositions and social norms, with some cultural contexts reinforcing sex-specific activity preferences (Biddle et al., 2019).

The interpersonal level of SEM underscores the vital influence of family members, caregivers, peers, and educators in shaping children's movement behaviours. This level acknowledges that behaviours do not occur in isolation but are significantly shaped by social interactions, role modeling, and environmental reinforcement (Jago et al., 2010). Research shows that children's engagement in movement behaviours is greatly impacted by parental attitudes, peer relationships, and school environments, which can either facilitate or hinder their adherence to the 24-hour movement guidelines (Feng et al., 2021; Rivera et al., 2024). Parental awareness of these guidelines has been shown to enhance compliance (Rivera et al., 2024).

A systematic review by Hesketh et al. (2017) identified a significant impact of parental perceptions and practices on the physical activity behaviours of children under six years old. This review highlighted factors that either encouraged or discouraged young children's participation in physical activities. Key motivators include parents acting as active role models, participating in physical activities with their children (co-participation), providing encouragement and logistical support, and emphasising the importance of physical activity as a core family value. These aspects highlight a broader socioecological perspective on how children's movement behaviours are influenced by both interpersonal and environmental factors.

Similarly, social and economic factors also affect movement behaviours at this level. Children from higher socioeconomic backgrounds may have greater access to recreational facilities, extracurricular sports programmes, and safe outdoor spaces, while those from lower-income families may encounter financial and environmental barriers to physical activity participation (Kracht et al., 2020).

At the organisational and community levels of the SEM, settings where children spend much of their time, such as schools, childcare centres, and community spaces, can significantly influence movement behaviours.

These contexts offer important structural and policy-driven opportunities to support physical activity, reduce sedentary time, and foster the development of healthy movement habits. ECEC settings, in particular, play a crucial role by providing both structured and unstructured opportunities for movement that support motor skill development, social interaction, and overall health (Pate et al., 2016). In Tanzania, for instance, the pre-primary curricula emphasise the importance of play within learning, reflecting a broader global recognition of its value in early childhood development (MoEST, 2016). Consequently, many early childhood settings incorporate designated play periods and provide basic play infrastructure, such as playground equipment including swings, to facilitate regular physical activity throughout the daily routine.

Research indicates that childcare centres with active play policies, outdoor playtime requirements, and staff trained to facilitate movement-based activities are likely linked to higher physical activity levels among preschool-aged children (Tucker, 2008). However, some centres prioritise academic readiness and structured learning, potentially at the cost of physical activity, thereby limiting opportunities for free play and movement. In such scenarios, children may have restricted access to outdoor play, leading to lower overall activity levels and increased sedentary time (Gubbels et al., 2010). To address this, policies mandating daily outdoor playtime, active indoor activities, and reduced screen time in early learning environments could, in theory, promote healthy movement behaviours from an early age. Nonetheless, the evidence supporting these recommendations primarily stems from high-income settings and may not be entirely applicable to LMICs contexts.

Within the environmental dimension of the SEM, both architectural structures and the natural environment can influence the extent of children's movement behaviours throughout the day. Factors like neighbourhood safety, walkability, access to parks, and overall urban design determine how much children engage in outdoor activities (Christian et al., 2015). For instance, well-designed urban environments that prioritise pedestrian-friendly infrastructure and provide accessible recreational spaces have been associated with higher physical activity levels. Conversely, areas characterised by high traffic density, inadequate infrastructure, and safety concerns are often linked to reduced active movement and increased sedentary behaviours (Zhang et al., 2024).

At the macro level, policies implemented by governments, educational institutions, and public health organisations can influence children's movement behaviours. National and international entities, such as the WHO and the Canadian Society for Exercise Physiology (CSEP), have developed 24-hour movement guidelines that include recommendations for physical activity, sedentary behaviour, and sleep (WHO, 2020; Tremblay et al., 2016) as discussed above.

Outside school settings, government investments in infrastructure and urban planning have contributed to promoting active lifestyles. Policies prioritizing the development of safe pedestrian pathways, accessible recreational spaces, and green environments have been linked to increased physical activity levels and reduced sedentary behaviours among children (Lovasi et al., 2011). For example, research shows that children living in neighbourhoods with well-maintained parks and playgrounds tend to be more physically active than those in areas lacking such facilities (Lambert et al., 2019).

The SEM offers a comprehensive and practical framework for examining the correlates and determinants of health behaviours and for developing interventions grounded in solid evidence. Its strength lies in Recognising that behaviours such as physical activity, sleep, and sedentary time are influenced by a complex array of factors operating at multiple interconnected levels, ranging from individual characteristics and interpersonal relationships to broader community contexts and policy environments (Arts et al., 2022).

However, applying the SEM in practice remains challenging, necessitating ongoing research to develop effective, scalable, and achievable interventions (Grêt-Regamey et al., 2017). A key challenge in implementing SEM-based interventions is the need for collaborative engagement among diverse stakeholders, including policymakers, educators, healthcare professionals, and community leaders. Ensuring alignment between policies, environmental structures, and individual behaviours requires well-coordinated, evidence-based strategies that consider real-world constraints. Additionally, the feasibility of such interventions often hinges on resource availability, institutional support, and cultural adaptability, further underscoring the importance of refining implementation approaches (Grêt-Regamey et al., 2017). Some researchers argue that the SEM alone may not provide a sufficiently comprehensive framework for designing and implementing effective interventions (Stormshak & Dishion, 2002; Gittelsohn & Lee, 2012).

These critiques highlight the need to integrate additional theoretical behaviour change models to strengthen intervention strategies and enhance their overall effectiveness (Schölmerich & Kawachi, 2016).

It is important to acknowledge that much of the evidence informing the application of the SEM to movement behaviours in children, as discussed above, originates from HIC settings. While the SEM offers a well-established framework for comprehending the multilevel determinants of health behaviours (Daniel Stokols, 1996), there exists a comparatively limited body of evidence from LMICs, including those in SSA, that examines how these multilevel influences shape 24-hour movement behaviorus in early childhood. Nevertheless, the fundamental principles of the SEM are likely to be broadly applicable across diverse settings, given that children's behaviours are universally influenced by interacting individual, social, environmental, and policy-level factors (Eriksson et al., 2025). The limited evidence base in LMICs therefore highlights an important gap in the literature, which this thesis seeks to address by examining the correlates of 24-hour movement behaviours within a SSA settings.

1.14 Conceptualisation and assessment of physical activity in early childhood

Literature employs various terminologies to define physical activity and its types, highlighting the construct's complexity and multidimensional nature. Physical activity is typically described as any bodily movement produced by skeletal muscles that leads to energy expenditure, as noted by Caspersen et al. (1985). It includes a spectrum of intensities and types, such as light, moderate, and vigorous activities. Common terms include exercise, which refers to planned, structured, and repetitive movements aimed at enhancing or maintaining physical fitness, and play, which is generally unstructured, spontaneous, and often associated with children's activities. Other distinctions include occupational, transport, household, and leisure-time physical activity, which classify activity by context or purpose. Understanding these distinctions is essential for accurately measuring and promoting physical activity across diverse populations. **Table 1-2** displays the various terms used to describe physical activity types.

Table 1-2: Various terminologies employed to define physical activity type

Terms	Definition	References
Active play	A form of total body movement in which young children exert energy in a freely chosen and unstructured manner.	Aadland et al., 2020; Johansson et al. 2015.
Structured physical activity	Activities that are performed by a child in a planned, deliberate way	Zeng et al 2017; Cheung et al.,2019.
Unstructured physical activity	Activities that are performed by a child that occur and spontaneously, sporadically, are often unplanned or unscheduled and involve self-directed games, play and other activities without external structures.	Burdette & Whitaker, 2005.
Energetic play	It is a form of physical activity which is characterised by vigorous movement and high levels of energy expenditure. It is particularly important in the context of early childhood education and care settings.	Nijhof et al., 2018.

1.14.1 Measurement of physical activity in children aged 3 to 4 years

Accurate measurement of physical activity in young children is essential for determining prevalence estimates, understanding associations with health outcomes, and assessing the effectiveness of interventions (Lettink et al., 2022), and is one of the stages of the BEF as summarised above. To achieve this, measurement tools and methodologies should ideally be valid, reliable, and feasible (Reilly et al., 2008; Trost, 2007).

Precise assessment enables researchers and clinicians to identify risk factors, establish benchmarks, monitor intervention outcomes, and guide behaviour change initiatives (Strath et al., 2013). Physical activity in early childhood is typically assessed using both subjective and objective measures. A systematic review conducted by Phillips et al. (2021) critically examined the validity, reliability, and feasibility of various instruments employed to assess physical activity and sedentary behaviour in children aged 3 to 7 years. The review highlights the complexity of measurement, attributed to their sporadic movement patterns and limited cognitive capacity for self reporting. The review identified accelerometers as valid instruments for assessing physical activity and sedentary behaviour, although they necessitate technical expertise. Proxy report instruments offered contextual insights but lacked robust validation. The most utilised methods for assessing physical activity in young children are outlined below.

1.14.2 Subjective methods for measuring physical activity in children aged 3 to 4 years

Subjective methods for assessing physical activity in children aged 3 to 4 years typically rely on data provided by parents or caregivers through interviews, surveys, recall techniques, or activity logs (diaries). Due to the limited cognitive abilities of young children, these instruments are often completed by parents or caregivers who serve as proxy reporters (Hnatiuk et al., 2014; Bingham et al., 2016).

These subjective measurements generally require parents or caregivers to estimate the frequency, intensity, and duration of physical activity within a specified timeframe, such as the past 24 hours or the previous week (Arts et al., 2022).

However, the validity of such data is constrained by the respondent's memory and awareness of the child's activities, particularly when activities occur outside the home in settings such as daycare centres or playgrounds. This increases the likelihood of recall bias as well as misreporting in the form of both overreporting and underreporting of behaviours (Hesketh et al., 2017). Furthermore, caregivers may encounter challenges in accurately distinguishing and classifying the intensity of physical activity (Hidding et al., 2017).

Further research has reinforced concerns regarding the accuracy of parent reported physical activity data in young children. For example, Pate et al. (2010) reported limited validity of parent reported physical activity assessments among children aged 3 to 5 years when compared with objective accelerometer measurements, finding only weak associations between subjective reports and objectively measured physical activity levels. Similarly, Sarker et al. (2015) observed that parents overestimated their children's physical activity by an average of 131 minutes per day for those under 6 years of age. In line with this evidence, Mwase-Vuma et al. (2022) reported that parent reported data in the SUNRISE study may have limited validity for assessing preschoolers' TPA. Their study found a very weak but statistically significant positive correlation and only slight agreement between parent reported TPA and accelerometer-measured TPA, with parents tending to substantially overestimate their child's TPA relative to accelerometer derived measurements. These findings highlight the limitations of subjective methods in yielding accurate quantitative estimates of physical activity.

Nevertheless, proxy report methods continue to be widely used, particularly in large scale studies or settings where device-based assessments are not feasible due to financial, logistical, or cultural constraints. Research has shown that these methods can still provide valuable insights. Palou et al. (2019), for example, found that a single parental question with five response options regarding physical activity in 3 to 5 year old children was positively associated with physical fitness indicators and negatively associated with markers of unhealthy body composition. These findings suggest that even simple subjective assessments can offer meaningful information about general activity levels, particularly in low resource settings.

In conclusion, although proxy reported tools for assessing physical activity in young children are subject to various biases and tend to have weaker validity compared to objective methods, they remain a practical and necessary option, especially in contexts where resources are limited. Their strength lies in the ability to provide behavioural and contextual information that device-based tools cannot capture, making them valuable complement to objective measures in mixed-methods approaches to early childhood physical activity research.

1.14.3 Objective methods for measuring physical activity in 3 to 4 year old children

Objective methods offer direct and measurable data on the physical activity levels of young children, serving as an alternative to the potential biases and inaccuracies found in subjective methods. These methods include direct observation, pedometers, accelerometers, and heart rate monitoring, and are most frequently used in early childhood studies (Pfeiffer et al., 2006). Each method has its advantages and disadvantages, making it crucial to consider its use in diverse research contexts.

1.14.4 Direct observation measurements

Direct observation methods involve researchers carefully watching and recording a child's physical activities, including their frequency, duration, type, and intensity. This can be performed live or through video recordings for subsequent examinations. One key benefit of this approach is its ability to capture the context in which physical activity occurs, such as environmental factors and social interactions (McIver et al., 2009). Some observational tools, such as the Observational System for Recording Physical Activity in Children Preschool Version (OSRAC-P), provide comprehensive data on physical activity levels, play environments, and levels of engagement, aiding in the categorisation of different activities (Brown et al., 2006).

Despite its benefits, direct observation requires considerable time and effort. The accuracy and precision of the collected data depend on the skill of the observer in accurately identifying and classifying physical activity. Observer bias is another possible disadvantage, as personal judgment may influence how activities are coded (Hinkley et al., 2012).

Additionally, continuous observation can lead to increased awareness, prompting children or caregivers to change their behaviour due to the presence of an observer (McIver et al., 2009). Direct observation measurements, however, require considerable resources and are not feasible for assessing overall daily activity levels (Sallis, 2010). This limits its application in large scale population studies or for prolonged monitoring durations.

1.14.5 Pedometer measurements

Pedometers are small, portable devices crafted to count the steps that an individual takes. This method provides a simple and cost-effective way to estimate overall physical activity levels in children aged 3 to 4 years. These devices are generally classified into two categories: mechanical pedometers, which detect steps through the motion of a spring-loaded lever arm activated by acceleration, and piezoelectric pedometers, which register steps when acceleration surpasses a predetermined threshold, subsequently aggregating these occurrences to calculate a total step count (Trost et al., 2012).

Recent technological advancements in pedometers have improved measurement accuracy by including time-stamped step counts, allowing researchers to analyse physical activity over different periods (Welk et al., 2000). Mwase Vuma et al. (2022) conducted a comprehensive validation study of pedometer step counts across 13 countries participating in the pilot SUNRISE study. The research concluded that a daily step count of 11,500, as proposed by De Craemer et al. (2015), exhibited excellent accuracy in evaluating compliance with the WHO's TPA guideline of 3 hours per day. The study suggests that while step-counting may not be optimal for measuring MVPA, it could serve as an effective, straightforward, and potentially cost-efficient method for assessing compliance with the TPA guideline in children aged 3 to 4 years, including those in low- and middle-income countries. While pedometers offer a cost-effective and unobtrusive method for monitoring movement, they are not ideal for differentiating between different types of physical activities, such as MVPA. Additionally, they do not provide information regarding the intensity or context of these activities. As a result, activities such as climbing, jumping, or participating in sports may not be accurately recorded, thereby diminishing the effectiveness of pedometers in assessing physical activity in young children under the age of five (Oliver et al., 2007).

1.14.6 Accelerometer measurements

An accelerometer is a small, wearable device that captures accelerations produced by the part of the human body to which it is attached, such as the waist or wrist (Migueles et al. 2017). It is commonly employed to estimate the time spent on sedentary behaviour and various physical activity intensities by applying age specific cutoff points (Hardy et al. 2013; Dollman et al. 2009).

Accelerometers are often considered the gold standard for measuring physical activity in young children because of their ability to capture movement intensity, frequency, and duration objectively and continuously (Pate et al., 2010). These devices operate by sensing the acceleration in multiple directions and converting this information into activity counts. The aggregate movement counts accumulated over a specified time interval, known as epoch length, are typically employed to ascertain activity intensity levels. Research suggests that utilising shorter epoch durations, generally 15 seconds or less, is most effective for capturing the sporadic and intermittent physical activity of children aged 3 to 4 years (Cliff et al., 2009). Accelerometers provide a high level of accuracy and reduce recall and other biases associated with subjective measures (Reilly et al., 2008).

Despite these strengths, accelerometers have limitations. They may underestimate non-ambulatory activities such as cycling or upper-body movement and provide little contextual information about where, how, and why activity occurs (Troost et al., 2012; Pedišić & Bauman, 2015). In addition, their high cost can make them impractical for large scale studies in low resource settings (Hinkley et al., 2012). Nevertheless, accelerometers remain widely regarded as valid and reliable tools for objectively measuring physical activity in young children, offering rich, minimally intrusive data that support comparisons by age, sex, or health status (Troost et al., 2005; Evenson et al., 2008). For comprehensive assessment, many researchers advocate for combining accelerometry with methods such as direct observation or caregiver proxy reports to capture both intensity and context (Oliver et al., 2007). However, this increases participant and researcher burden and costs.

A systematic review and meta-analysis by Bornstein et al. (2011) examined accelerometer derived physical activity levels in young children aged 3 to 5 years, highlighted several critical methodological challenges and implications.

The review reported wide variability in moderate-to-vigorous physical activity levels (MVPA), ranging from 40 to 100 minutes per day. This inconsistency was largely attributed to methodological differences, particularly the use of varying accelerometer cut points to define MVPA. This methodological problem is known as cut point non-equivalence, which complicates efforts to accurately estimate activity prevalence in this population and limits the comparability of findings across studies. The authors emphasised the need for standardised and widely accepted protocols for processing and interpreting accelerometer data to enable more accurate and comparable physical activity estimates. They also highlighted other methodological issues, such as the influence of epoch length and the importance of reporting data separately by sex. Without standardisation, it remains difficult to determine whether young children are meeting recommended physical activity guidelines, thereby limiting the development of effective public health policies and interventions. The authors recommended further calibration and validation studies and proposed developing an equating system to help harmonise data across studies.

1.14.7 A minimum wear criterion using accelerometer data

When using accelerometers to assess physical activity in children, it is important to determine if each child has worn the device long enough to provide a reliable and accurate measure of their typical activity levels (Rich et al., 2013). Children's physical activity can vary greatly from day to day, leading to substantial fluctuations in physical activity levels. For example, a child might be more active on days when they have physical education (PE) classes at school or play outside, compared to days when they do not have PE. Moreover, adherence to wearing accelerometers is often inconsistent, with children seldom wearing the device for the entire period specified by researchers.

Therefore, establishing suitable wear-time criteria is an essential methodological step to ensure the inclusion of valid data in subsequent analyses. This process involves determining both the minimum number of wear minutes per day and the minimum number of valid days needed to accurately represent habitual physical activity behaviours (Rich et al., 2013). Setting these thresholds helps reduce the risk of misrepresenting a child's typical activity pattern due to insufficient data or unusual activity on isolated days.

A key factor influencing the validity of accelerometer derived data is the duration of daily wear time. Hinkley et al. (2012) investigated this issue to establish the minimal number of monitoring days required for a reliable estimate of physical activity in young children aged 3 to 5 years. Their findings indicated that a minimum of 2.7 days of data, with at least 10 hours of wear time per day, was needed to reach a reliability coefficient (intra-class correlation, ICC) of 0.7, which is generally regarded as the standard for acceptable reliability for measurement in individual children. If the daily wear time was reduced to 7 hours, the required number of days increased to 3.3, illustrating the relationship between daily wear time and the number of valid days needed to ensure reliable data.

It has been suggested that increasing the number of days, as opposed to having fewer, is advantageous for capturing variability and thereby obtaining a more stable and reliable estimate of habitual physical activity. This is attributed to the fact that reliability enhances with increasing number of days and the daily wear time (Reilly et al., 2008; Penpraze et al., 2006; Hislop et al., 2014).

1.15 Sedentary movement behaviours

Sedentary behaviours (SB) can be categorised into screen-based and non-screen-based activities. Screen-based SB includes behaviours such as watching television, using smartphones, or playing video games. In contrast, non-screen-based SB involves activities such as reading, sitting while doing homework, or when travelling (Tremblay et al., 2017). Among children, screen-based SB is the predominant form, primarily driven by the increasing accessibility of digital media and entertainment (Cliff et al., 2016).

It is crucial to differentiate between sedentary behaviours and physical inactivity. The former involves specific low energy expenditure postures and behaviours, whereas the latter refers to not complying with physical activity guidelines (Pate et al., 2008). Additionally, sedentary behaviours should not be mistaken for a total lack of physical activity, as a person might participate in some physical activities while still spending a significant amount of time being sedentary (Tremblay et al., 2017).

A recent study introduced a novel approach for classifying sedentary behaviours, distinguishing between passive sedentary activities, such as television viewing, and mentally active sedentary behaviours, such as reading or engaging in cognitively stimulating tasks (Hallgren et al., 2020).

For young children, appropriate sedentary engagements may also include assembling puzzles, listening to stories, or engaging in screen-based games.

Screen time is one of the most prevalent and extensively studied forms of sedentary behaviour among young children, due to its prevalence and possible associations with obesity and other health concerns. This section, however, is specifically devoted to the measurement of sedentary behaviours, which often include but are not limited to screen time.

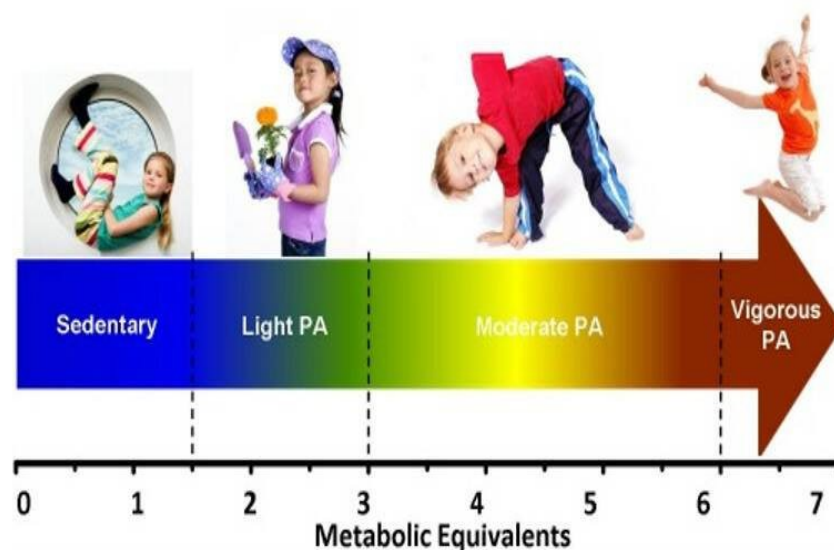


Figure 1-6: The energy expenditure continuum. Adapted from the Sedentary Behaviour Research Network (SBRN, 2012).

1.15.1 Measurement of sedentary behaviour in 3 to 4 year old children

Accurate measurement of sedentary behaviour is crucial for understanding its health impacts and for informing the development of effective interventions. The BEF offers a robust and systematic structure for investigating this issue across the various phases of research (Marshall & Ramirez, 2011), as previously discussed. Similar to physical activity, sedentary behaviour in children can be assessed using both subjective and objective methods, as illustrated in **Figure 1-7**.

There is a degree of overlap between the features of sedentary behaviour and physical activity measurements. Given these similarities, this section will build upon the aspects of measurement previously discussed in section 1.14.2, further elaborating on how different methodologies are applied to understand sedentary behaviour in children.

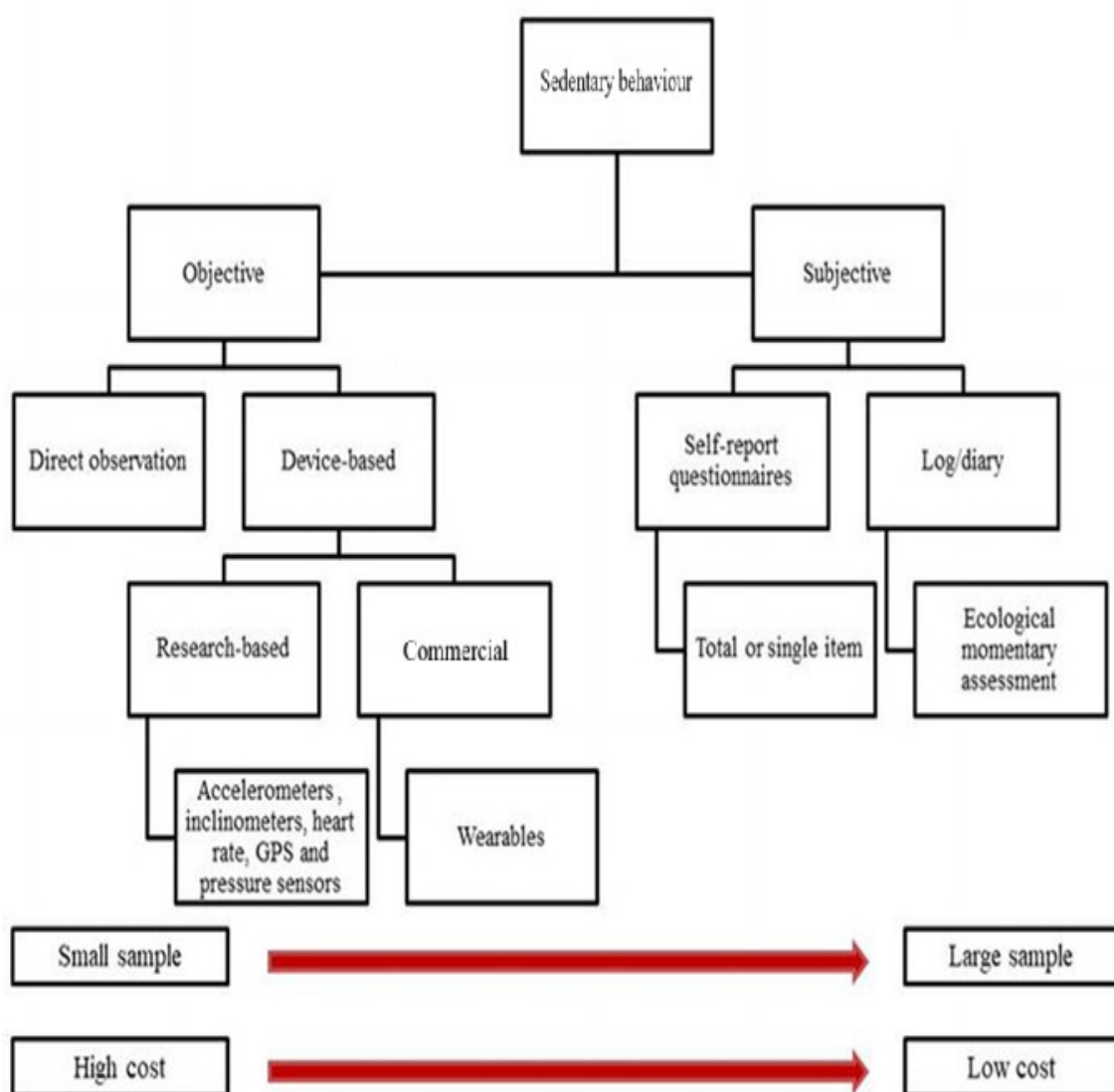


Figure 1-7: Flow chart of different methods to assess SB. Redrawn from Marconcin et al.,2021.

1.15.2 Subjective methods of sedentary behaviour measurement in children aged 3 to 4 years

Subjective methods, such as self report questionnaires (for older children and adolescents), proxy reports for younger children, and activity logs or diaries, allow for a contextual understanding of sedentary activities, but may be prone to recall bias and misreporting (Kohl, Fulton, & Caspersen, 2000; Aunger & Wagnild, 2020).

Children under the age of 10 years lack the cognitive ability to accurately recall and report their activities (Loprinzi & Cardinal, 2011; Welk et al., 2000). Consequently, parents or caregivers typically fill these out as a proxy for their children (Welk et al., 2000).

A number of comprehensive reviews have examined the reliability and validity of sedentary behaviour measurement tools in children and adolescents (Phillips et al., 2021; Lubans et al., 2011), with key findings summarised in **table 1-3**.

Table 1-3: Evidence: Summary of validity and reliability of measurement tools for 24-hour movement behaviours

Systematic reviews (Author/year)	Main focus	Measurement methods	Key findings	Recommendations
Antsygina et al. (2025)	Assessed reported sleep measures for children aged 0 to 4.99 years	Parent reported instruments, questionnaires	No valid/reliable tools identified; studies showed methodological flaws and lacked diverse samples	Develop standardised, psychometrically sound tools with inclusive and cross-cultural considerations
Hidding et al. (2018)	Evaluated the validity and reliability of self and proxy report questionnaires used to assess sedentary behaviour and physical activity in individuals under 18 years	Questionnaires (self-report and proxy report) measuring screen time, sitting time, physical activity and total sedentary behaviour	None of the included questionnaires met criteria for both validity and reliability; studies often had poor or fair methodological quality; content validity was inconsistently addressed	improve questionnaire design through rigorous development processes; incorporate objective tools for construct validation (e.g., accelerometers, inclinometers); ensure content validity is thoroughly evaluated
Byrne et al 2021	The objective of this study is to systematically review and evaluate the measurement tools used to assess screen time in children aged 0 to 6 years, with a focus on summarising their characteristics, assessing the reporting of psychometric properties, and examining temporal trends in both the assessment methods and the quality of psychometric reporting.	Self report or proxy report questionnaires	Research on young children's screen time has increased, with measures expanding beyond TV to other devices. However, only 40% of articles provided a citation for the screen time measure used, and only 11% reported on the reliability and/or validity of the measure. Psychometric properties were reported, the evidence was generally adequate, with 84%	No studies utilised device-based methods to objectively measure screen time, despite calls in the literature to move beyond reliance on parent report measures.

			reporting reliability and 28% reporting validity.	
Phillips et al. (2021)	To assess the validity, reliability, and feasibility of tools for measuring physical activity (PA) and sedentary behaviour (SB) in preschool aged children (3 to 7 years).	Systematic review of studies evaluating different measurement tools, including device-based accelerometers and proxy reported methods.	Accelerometers showed promising results. Proxy reported tools offer context but have weak evidence.	Highlights feasibility but also showed complexity of measuring PA and SB in under 5s
Lubans et al. (2011)	Assessed validity and reliability of sedentary behaviour measures in children and adolescents aged 3 to 18	Accelerometers, self-report, proxy report, direct observation	Accelerometers were most valid; self-proxy reports showed inconsistent reliability	Prioritise accelerometers; use multi-method approaches; standardise definitions and protocols
Rodrigues et al. (2023)	Assessed the measurement properties of questionnaires evaluating 24-hour movement behaviours (physical activity, sedentary behaviour, and sleep) in children and adolescents (younger than 18 years)	Self-report and proxy report questionnaires targeting one or more movement behaviours	No questionnaire demonstrated both criterion validity and reliability; none reflected the 24-hour movement paradigm; methodological diversity hindered comparison across tools	Develop new or adapt existing tools that align with the 24-hour movement behaviour paradigm; ensure comprehensive validation (validity, reliability, responsiveness); apply standardised methods to enable cross-study comparisons; prioritise tools that assess guideline compliance

PA-Physical activity

SB-Sedentary behaviour

Phillips et al. (2021), in their review focusing on children aged 3 to 7 years, noted that proxy report tools offered important contextual information regarding the nature, setting, and purpose of sedentary behaviours. For example, proxy reports can help differentiate between screen time for educational purposes and recreational viewing, or between passive sedentary behaviours and those involving light engagement, such as reading. However, despite these advantages, the review also highlighted the limited validation of proxy report tools, with concerns surrounding their reliability and accuracy. These limitations are primarily attributed to the challenges caregivers face in recalling and accurately estimating their child's behaviour throughout the day, especially in settings where the child is not under direct supervision, such as in daycare or preschool.

Similarly, Lubans et al. (2011) conducted a comprehensive assessment of the validity and reliability of various sedentary behaviour measurement tools used in children and adolescents aged 3 to 18 years. Their review critically evaluated both objective and subjective instruments, including accelerometers, self reports, and proxy reports. While accelerometers were consistently identified as the most accurate and reliable method for quantifying sedentary time, subjective methods particularly self-report and proxy report questionnaires demonstrated inconsistent reliability across studies. The reliability of self-reported and proxy reported sedentary behaviour measures varied considerably depending on factors such as the age of the child, the recall period, the behavioural domains assessed, and the setting in which the behaviour occurred. For younger children, proxy reports completed by parents or caregivers were necessary due to developmental limitations in the child's cognitive ability to recall and accurately report behaviours. However, these proxy reports often suffered from recall bias and reporting inaccuracies, particularly when caregivers were not present during significant portions of the child's day, such as at school or in childcare settings. Lubans et al. also observed that many self report and proxy report tools lacked standardisation in their development, contributing to poor comparability across studies. Moreover, the inconsistent reliability of these tools raised concerns about their suitability for use in surveillance and intervention research. Despite these limitations, self- reports and proxy reports were recognised for their ability to provide contextual information about the types of sedentary behaviour (e.g., screen time, reading, or doing homework), which objective measures like accelerometers cannot distinguish.

1.15.3 Objective methods of sedentary behaviour measurement in children aged 3 to 4 years

Objective methods, such as direct observation and accelerometers, are commonly used to assess sedentary behaviour among young children. Although these methods can potentially provide more accurate and systematic approaches than subjective reports do, they also present unique challenges, particularly when applied to children aged 3 to 4 years.

Accelerometers are widely used to objectively measure sedentary behaviours because they can accurately detect low energy expenditure. However, a major limitation of the accelerometer is its inability to identify different types of sedentary activity. For example, while an accelerometer can show that a child is not active, it cannot determine whether the child is quietly sitting while participating in educational activities such as reading or drawing, or if they are simply watching television.

There is a risk of incorrectly identifying sleep and non wear periods as sedentary time when using accelerometers, a limitation that is particularly relevant for young children who frequently take naps during the day (Choi, Liu, Matthews, & Buchowski, 2011).

When a child is sleeping, the accelerometer registers zero or close to zero movement counts, as children of this age do not remain entirely motionless during sleep. Misclassification can be minimised depending on the wear time rule applied to accelerometer data, for example, 20 minutes versus 60 minutes of consecutive zeros (Cliff et al., 2016; Trost et al., 2005). This highlights the importance of carefully considering wear-time protocols when analysing accelerometer data in young children.

A major limitation of accelerometers is their inability to provide insights into types of sedentary behaviour and screen time. Not all sedentary activities have adverse effects on health as noted above. Certain non-screen sedentary behaviours, such as reading, crafting, and drawing, have been identified as having potential benefits for cognitive and social development as noted above (Carson et al., 2016; Poitras et al., 2017). This lack of contextual information is especially problematic when evaluating screen-based sedentary behaviour, which is of growing concern due to its specific implications for cognitive, social, and physical health in early childhood. Objective methodologies cannot currently directly quantify sedentary screen time.

Sedentary screen time, encompassing activities such as television viewing, video gaming, and the use of tablets and smartphones, is among the most extensively examined sedentary behaviours in young children. The absence of objective data on screen time in this demographic has been recognised as a research gap by the WHO (Kahn et al., 2021). Presently, screen time is predominantly assessed through proxy reports from parents or caregivers, which may introduce biases, such as underreporting or overestimating screen exposure due to recall difficulties (Lubans et al., 2011).

Several systematic reviews underscore these measurement challenges. Lubans et al. (2011) evaluated the validity and reliability of sedentary behaviour measures among children and adolescents aged 3 to 18 years, including accelerometers, self reports, and proxy reports. The review concluded that accelerometers were the most valid method for measuring sedentary behaviour. The authors recommended prioritising the use of accelerometers, adopting multi-method approaches, and standardising definitions and measurement protocols. Similarly, Byrne et al. (2021) conducted a systematic review focusing specifically on the measurement of screen time in children aged 0 to 6 years. Reviewing 622 eligible studies published between 2009 and 2020, the authors found that most screen time measures consisted of just one to three items focused primarily on daily duration. Few measures addressed the nature of the content (11%) or co-viewing behaviours (7%). Only 11% of studies reported any psychometric properties, with reliability reported in 58 studies, validity in 19, and both in only eight.

The review highlighted a gradual evolution of measurement tools to reflect children's exposure to mobile devices alongside traditional television, particularly from 2015 onward. However, it concluded that the overall quality of measurement remains poor, with limited validation and inconsistent reporting. The authors called for the development of more robust, psychometrically sound tools that better capture the complexity of screen time within today's rapidly evolving digital landscape.

In conclusion, although objective measures such as accelerometers remain essential for accurately quantifying total sedentary time, they cannot capture screen-based behaviours, which have unique implications for young children's health and development. Proxy reports remain the primary method for assessing screen time but suffer from methodological weaknesses.

Therefore, it is often recommended to integrate both objective methods and proxy parent reports to capture associated contexts effectively (Kang & Rowe, 2015). Given the growing concerns about the health risks of prolonged sedentary time, especially in early childhood, research continues to refine measurement techniques, especially for screen time, and explore effective intervention strategies to reduce excessive SB (Okely et al., 2017).

1.16 Measurement of sleep behaviour

1.16.1 Objective methods of sleep behaviour measurement in children aged 3 to 4 years

Objective methods rely on technological tools to capture quantifiable, movement-based data on sleep-wake cycles. In young children, the most commonly used objective method is the use of accelerometers. These devices estimate sleep duration and quality by tracking patterns of movement and rest, offering a non-invasive and continuous method for monitoring sleep in naturalistic settings over several days or weeks (Sadeh, 2011). Accelerometers are particularly well suited for use in early childhood, where traditional laboratory-based methods such as polysomnography are often impractical due to cost, complexity, and the burden on families.

In children, sleep duration is often the primary focus because of its measurable impact on growth and cognitive development. However, increasing evidence has highlighted the significance of sleep quality, as fragmented or inefficient sleep can negatively affect emotional regulation, attention, and overall well-being (Gruber et al., 2014).

Recent advancements have improved the accuracy of accelerometer-based sleep assessments. For instance, Tracy et al. (2021) developed a decision-tree algorithm that achieved 95.6% accuracy in detecting sleep and wake periods using data from waist-worn ActiGraph GT3X+ devices. This study, conducted in a large, socioeconomically diverse sample of young children aged 3 to 6 years, demonstrated that high-fidelity, algorithm-driven analysis of accelerometry data is feasible and can closely approximate manually scored sleep periods. These findings underscore the potential of accelerometers to provide valid, scalable measures of sleep behaviour in young children.

Using accelerometers for sleep measurement may be less feasible in resource poor settings. However, despite their promise, objective sleep assessments using accelerometry remain technically complex and resource intensive.

Accurate data interpretation often requires expert oversight, sophisticated algorithms, and detailed wear-time protocols to distinguish sleep from sedentary wakefulness or non wear periods. Furthermore, compliance with wearing devices can be challenging in younger children, and equipment costs, data processing demands, and technical training requirements can limit the feasibility of widespread use.

1.16.2 Subjective methods of sleep behaviour measurement in children aged 3 to 4 years

Subjective methods for assessing sleep encompass parent or caregiver-reported questionnaires, sleep diaries, and structured interviews. These tools are prevalent in studies involving young children under the age of ten, who are generally unable to reliably self-report their sleep behaviours. For example, Sadeh (2008) noted that proxy reports, especially from parents, are widely used in paediatric sleep research due to young children's limited cognitive and verbal abilities to accurately describe their own sleep patterns. Similarly, the National Sleep Foundation (2014) highlights that parental reports remain the primary method of assessing sleep in children under ten, given the challenges of self-reporting at this developmental stage.

Despite the well-established importance of sleep in early childhood, a systematic review by Antsygina et al. (2025) revealed a critical lack of validated and reliable tools for assessing sleep in children aged 0 to 4.99 years.

The review focused on parent reported instruments and questionnaires, identifying numerous methodological limitations in existing studies, including weak study designs, inadequate statistical analyses, and inconsistencies in sleep related terminology and definitions. Furthermore, key population groups such as single parents and mothers under the age of 18 were often underrepresented, limiting the generalisability of findings. Importantly, none of the reviewed tools had undergone a comprehensive evaluation across all relevant psychometric properties, underscoring the urgent need for robust, inclusive, and methodologically sound tool development in this field.

In contrast, a more recent study by Zhang et al. (2024) evaluated the measurement properties of the SUNRISE study parent questionnaire, which was designed to assess sleep behaviours and related family practices in children aged 3 to 4 years. The study demonstrated moderate to strong correlations between parent reported sleep duration and timing and accelerometer derived measures, supporting the questionnaire's validity, particularly for use in large scale and resource-limited settings. Notably, the mean error for reported average nighttime sleep duration was only 9 minutes per night, with the mean nighttime sleep duration averaging approximately 10 hours per night, indicating strong agreement with objective measurements. However, the SUNRISE questionnaire showed limitations in accurately capturing sleep quality and night to night variability, suggesting that objective, device-based methods remain necessary for more precise individual-level assessments (e.g., actigraphy, polysomnography). Furthermore, findings from Mindell et al. (2013) highlight a gap in parental awareness regarding children's sleep quality, reinforcing the need for targeted sleep health education for caregivers.

While the SUNRISE questionnaire may not provide precise individual estimates of sleep duration and other aspects of sleep, it is well suited for group level surveillance and large-scale epidemiological research. The authors advocate for its use alongside objective tools in clinical or high stakes contexts to mitigate individual measurement error (Zhang et al., 2024).

1.17 The SUNRISE International Study of movement behaviours in the early years

The work presented in the the current thesis was partially informed by the SUNRISE International study, an international cross-sectional investigation into 24-hour movement behaviours in early childhood (<https://sunrise study.com>). This study was initiated in response to the lack of data on young children's movement behaviours, especially in LMICs (Roll et al., 2020). It was designed to gather data on movement behaviours among children aged 3–4 years using the standardised protocol described above, thereby establishing key benchmarks for ongoing surveillance and monitoring compliance with global guidelines.

Drawing on the BEF, the study aimed to: (1) determine the proportion of children meeting the WHO's 24-hour movement behaviour guidelines; and (2) explore correlates, i.e., differences in compliance based on demographic, socioeconomic, and contextual factors, including urban versus rural settings. These objectives are intended to generate policy-relevant evidence that can guide global and national efforts to promote healthy childhood development.

Participating countries implemented the SUNRISE International Study protocol in two phases: an initial pilot study involving 100 children to assess the acceptability and feasibility of the measurement and other procedures, followed by a main study targeting a sample of 1,000 children (Okely et al., 2021).

At the time of writing this thesis, the SUNRISE initiative had expanded to include 64 countries spanning low- to high-income settings. Of these, 12 countries were from SSA (<https://sunrise study.com>). The expansion of the SUNRISE International Study over the years has contributed to growing evidence on compliance with global movement behaviour guidelines in early childhood globally, including in LMICs. Nevertheless, published evidence on compliance with the global guidelines among young children in SSA remains limited, with only a small number of studies reporting findings from this region (Chong et al., 2024).

The recruitment of these countries was largely accomplished through the existing networks and partnerships of the SUNRISE Leadership Group, with further growth supported by invitations and expressions of interest.

All country teams receive comprehensive training from the SUNRISE Coordinating Centre prior to data collection, ensuring consistent implementation and methodological rigor. The Coordinating Centre also provides key research tools, including ActiGraph accelerometers for objectively measuring physical activity and sleep, and iPads pre-loaded with REDCap for secure digital data capture and management. The level of equipment support is tailored to the needs and capacities of each country.

Since the SUNRISE study's launch in 2018, many countries have completed the pilot phase and begun generating valuable data. However, progress has varied, with financial constraints posing significant challenges, particularly in LMICs. In contrast to many international studies, the SUNRISE study adopts a model in which participating countries are responsible for securing their own funding for the main study.

This funding structure has posed a significant barrier to implementation, particularly in resource-constrained settings.

The primary aim of the pilot work was to test and refine the study protocol across various local contexts (In, 2017). Data collected during the pilot phases were continuously analysed to improve the study's methods and measures. Methodological adjustments were made between phases due to practical challenges encountered during implementation. For example, in Phase I, the protocol incorporated the use of the activPAL device; however, this was discontinued in Phase II due to reported discomfort, skin irritation, and concerns regarding wear-time compliance (Okely et al., 2021). Consequently, Phase II adopted the ActiGraph device, which proved more feasible and acceptable for the study populations.

In Tanzania, the pilot study is described in chapter three and was successfully completed with a sample of 110 children. This initial phase was important for evaluating the feasibility and contextual suitability of the SUNRISE protocol. It provided key insights into recruitment logistics, equipment uses, and the cultural acceptability of the study tools. With these lessons learned and adaptations made, Tanzania is now prepared to progress to the main study, enrolling roughly 1,000 children from both urban and rural settings. However, the successful implementation of this next phase depends on the availability of sufficient financial resources.

In conclusion, the SUNRISE international study represents a significant step forward in addressing global evidence gaps on movement behaviours in early childhood, with particular emphasis on the prevalence and correlates of meeting movement behaviour guidelines which corresponds to stage three of the BEF, particularly in LMICs. By generating robust, comparable data and supporting the development of local research capacity, SUNRISE has the potential to influence global public health efforts and improve early childhood health outcomes across diverse settings.

1.18 Research gaps in 24-hour movement behaviours in Tanzania and Sub-Saharan Africa

By employing the SUNRISE methodology, this thesis seeks to address existing knowledge gaps by collecting and presenting original data from Tanzania regarding the 24-hour movement behaviours of children aged 3 to 4 years (refer to chapter 3).

Prior to this study, there was a lack of nationally representative data on the movement behaviours of Tanzanian children within this age group.

Therefore, the study offers novel insights into how these children allocate their time to physical activity, sedentary behaviours, and sleep over a complete 24-hour period. The findings are important contributions to the limited research on movement behaviours in Tanzanian children, contributing to a strong evidence base that may be used to inform future research, policy development, and intervention strategies specifically tailored for this group of children and context.

1.19. Aim and research questions

The primary objective of this doctoral thesis was to examine 24-hour movement behaviours in children aged 3 to 4 years in SSA. To address this over-arching aim, the following research questions were investigated:

Research question 1:

What evidence is available on compliance with the WHO 2019 24-hour movement behaviour guidelines among 3–4 year olds in SSA?

Sub-question: What gaps exist in the available evidence on compliance with the 24-hour movement behaviour guidelines among 3–4 year olds in SSA, and what future research questions should be explored?

Research question 2:

How feasible is the SUNRISE protocol in Tanzania, and what modifications would be required for a future larger SUNRISE main study?

Sub-question:

- What is the preliminary prevalence of Tanzanian 3- and 4 year old children meeting the WHO guidelines for physical activity, sedentary behaviour, restrained sitting, and sleep?

Research question 3:

What are the prevalence and correlates of meeting the WHO 24-hour movement behaviour guidelines among children aged 3–4 years in low- and middle-income countries (LMICs) in an international cross-sectional study?

Sub-question:

How does urban versus rural living location influence compliance with the WHO 24-hour movement behaviour guidelines among children aged 3–4 years in low- and middle-income countries (LMICs) in an international cross-sectional study?

1.20 Overview of the Thesis

This thesis comprises three manuscripts presented as individual chapters: a systematic literature review (Chapter 2), an original research study utilising primary data collection (Chapter 3), and a study employing secondary data analysis (Chapter 4). Each manuscript constitutes a separate chapter within the thesis. **Table 1-4** provides a summary of the chapters included in this thesis.

Table 1-4 Thesis Outline

Chapter 1: Introduction and literature review This chapter introduces the research topic and provides context about childhood overweight and obesity and 24-hour movement behaviours in Tanzania. It introduces 24-hour movement behaviours, including physical activity, sedentary behaviour, and sleep, and presents the theoretical framework. The chapter reviews evidence on associations between movement behaviours and health outcomes in children aged 3 to 4 years, identifies potential correlates, and highlights research gaps, particularly the lack of data from African countries like Tanzania. Finally, the chapter presents an overview of the thesis structure, outlining how each subsequent chapter contributes to addressing the overall research aims.
Chapter 2: Paper 1 (Study 1) Preschool children’s compliance with the WHO 24-hour movement behaviour guidelines: A systematic review of Sub-Saharan African studies (Nusurupia et al. 2020). This chapter addresses research question 1: “What evidence is available on compliance with the 24-hour movement behaviour guidelines among 3–4 year olds in SSA”? This question was addressed through a systematic review of previous studies that reported on compliance with the 24-hour movement behaviours in children aged 3 to 4 years in SSA.
Chapter 3: Paper 2 (Study 2) Twenty-four hour movement behaviours in the early years in Tanzania: SUNRISE pilot study (Nusurupia et al. 2024) This chapter examines research question 2: "What is the practicality of implementing the

SUNRISE protocol in Tanzania, and what adjustments might be necessary for a larger future study?" This study involved the primary collection of data to evaluate the feasibility of employing accelerometers for the measurement of 24-hour movement behaviours, encompassing physical activity and sleep. Additionally, it included parent reported data on screen time, sleep duration, and time spent sitting restrained, as well as information on enrolment and dropout rates.

Chapter 4: Paper 3 (Study 3) Urban versus rural differences in meeting 24-hour movement behaviour guidelines among 3–4 year olds: An analysis of SUNRISE pilot study data from 10 LMICs (Nusurupia et al. 2024)

This chapter addresses research question 3: What are the prevalence and correlates of meeting the WHO 24-hour movement behaviour guidelines among children aged 3–4 years in LMICs in an international cross-sectional study? In addition, it examined the following sub-question: How does urban versus rural living location influence compliance with the WHO 24-hour movement behaviour guidelines among children aged 3–4 years in LMICs in an international cross-sectional study? This analysis is based on secondary data, utilising information from the 10 LMICs that had completed SUNRISE data collection before the onset of COVID-19.

Chapter 5: General discussion and conclusions

This concluding chapter summarises the main findings of this thesis and discusses them within the broader body of evidence. It further discusses the implications of the study's findings the overall strengths and limitations of the thesis. Additionally, this chapter will summarise the key points from the thesis studies, identify gaps in the existing literature, and propose areas for future research.

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Chapter 2: 3 to 4 year old children's compliance with the WHO 24-hour movement behaviour guidelines: A systematic review of SSA studies

2.1 Preamble

This chapter presents a systematic review of studies examining the compliance of 3 to 4 year old children with the WHO 24-hour movement behaviour guidelines in SSA. It addresses a significant gap in the existing literature by synthesising available evidence on young children's physical activity, sedentary behaviour, and sleep within the SSA region. The findings of this review were published in the African Journal for Physical Activity and Health Sciences, and the manuscript is included here in its published format.

2.2 An overview of the chapter and its findings

In 2019, the review identified a significant research gap, with limited evidence regarding movement behaviours in 3–4 year olds in SSA. The review indicated that very few studies had examined the compliance with 24-hour movement behaviours among 3–4 year olds in this region. Furthermore, preliminary evidence suggested that the few studies identified reported low compliance with these movement behaviour guidelines. At that time, surveillance of the movement behaviours was extremely limited, and there was a clear need for more representative data from this under researched region.

Since the publication of the review, several important studies have emerged that contribute to the growing body of knowledge on movement behaviours among young children SSA. Notably, a study conducted in Ethiopia by Abdeta et al. (2024) reported unexpectedly high levels of compliance, with 58% of young children meeting three WHO movement behaviour guidelines (physical activity, sedentary behaviour, and sleep). Another recent global study conducted by Chong et al. (2024) examined children aged 3 to 4 years across 33 countries and revealed that compliance with these guidelines was generally low, with only 14% of children meeting the same three guidelines. Additionally, Chong et al. (2024) underscored the limited representation of SSA, as the sample included only four countries from this region. As summarised in **Table 2-1**, considerable variation in compliance is evident across studies conducted in SSA.

Table 2-1: Summary of recent studies examining compliance with WHO 24-hour movement behaviour guidelines among children aged 3–4 years in sub-Saharan Africa

Study	Country	Age/Sample size	Methods	Key Findings	Measurements note/limitation
Abdeta et al.,2024	Ethiopia	N = 430 3-4 years	PA (TPA and MVPA) and Sleep: Accelerometers (ActiGraph) ST: Parent reported RS: Not Reported	58% complied with the 3 WHO guidelines	Meeting the guidelines was associated with urbanicity not the child's sex, and parent education; Large sample size; Possible underestimation of ST due to parent-report; Mixed measurement approaches
Mwase - Vuma et al.,2024	Malawi	N = 417, 3-4 years	PA (TPA): Accelerometers (ActiGraph) ST: Parent reported Sleep: Parent reported RS: Parent Reported	60% complied with the 4 WHO guidelines	TPA based on step counts; rural children more active than urban; inclusion of restrained sitting affects comparability; mixed measurement approaches; Large sample; Possible underestimation of ST/RS and sleep due to parent-report.
Chong et al.,2024	33 Countries	N=7017 (SSA)	PA (TPA and MVPA):	14% complied with	Larger sample from multiple

	(SSA =4)	N=286) 3-4 years	Accelerometers (ActiGraph) ST: Parent reported Sleep: Parent reported RS: Not Reported	the 3 WHO guideline	countries; Mixed measurement approaches; SSA underrepresentation; Potential urban bias; Possible underestimation of ST and sleep due to parent-report.
Draper et al., 2020	South Africa	N = 88 3-4 years	PA (TPA and MVPA): Accelerometers (ActiGraph) ST: Parent reported Sleep: Parent reported RS: Parent Reported	26% complied with the 4 WHO guideline	Small pilot sample; Mixed measurement approaches; Limited generalisability; Possible underestimation of ST/RS and sleep due to parent-report.
Munambah et al., 2021	Zimbabwe	N = 81 3-4 years	PA (TPA): Accelerometers (ActiPAL) ST: Parent reported Sleep: Parent reported RS: Parent Reported	23% complied with the 4 WHO guideline	Small pilot sample; PA measured as stepping time; methodological differences limit comparability; Possible underestimation of ST/RS and sleep due to parent-report; Mixed measurement approaches.

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Abbreviations: PA = Physical activity, MVPA = Moderate-to-vigorous physical activity, TPA = Total physical activity, N = Sample size, RS = Restrained sitting, ST = Screen time, SSA = Sub Saharan Africa,

These differences are likely explained by variations in study design, measurement approaches, and contextual factors. For example, while several studies used accelerometry to assess physical activity, sedentary behaviour and sleep were often parent-reported, introducing potential reporting bias. In addition, differences in urban–rural composition, access to screen-based devices, and cultural practices may influence children’s movement behaviours and contribute to the observed variability in compliance. Determining whether observed differences in compliance reflect methodological variation or genuine contextual differences requires comparisons across studies that are directly comparable, i.e. those employing consistent measurement methods and operationalise compliance in the same way. However, even within SUNRISE Study publications to date, methodological approaches have not been entirely consistent, and compliance has not always been defined or operationalised in the same way (Mwase-Vuma et al., 2025).

Comparing the evidence base before and after the systematic review indicates that, while some progress has been made in advancing understanding of movement behaviours among young children in sub-Saharan Africa (SSA), important gaps remain. Regional evidence has improved slightly through recent SUNRISE Study pilot studies (Draper et al., 2020; Munambah et al., 2021; Hossain et al., 2021; Ltifi et al., 2024), as well as non-SUNRISE studies (Rae et al., 2021; Tomaz et al., 2019). However, these studies are often limited by small sample sizes, pilot designs, and inconsistencies in measurement approaches, which constrain comparability and generalisability. Consequently, there remains an urgent need for larger, more representative, and methodologically consistent studies to strengthen the evidence base across the region. This necessity is particularly pressing given the region's rapidly expanding child population and the increasing prevalence of childhood obesity associated with lifestyle factors as noted in chapter 1. By 2025, Africa’s childhood population is projected to reach 1 billion, which will make it the largest childhood population compared to all other continents (United Nations Children's Fund, 2019).

2.3 The contribution of the article to this thesis

This systematic review directly informed the development of Study 2, the SUNRISE pilot study in Tanzania presented in Chapter 3. The review established the urgent need for locally generated data on children’s movement behaviours in SSA.

Specifically, Study 1 highlighted:

- The lack of prevalence data on compliance with the 24-hour movement behaviour guidelines.
- The need for reliable, valid, and feasible measurement protocols suitable for low resource settings.

Study 2 (Chapter 3) built upon these findings by assessing the feasibility of implementing the SUNRISE protocol in Tanzania. While feasibility studies are inherently limited in their capacity to accurately estimate prevalence due to small and potentially unrepresentative samples, they are instrumental in determining the protocol's suitability for larger scale studies that can produce reliable prevalence estimates. Consequently, this study contributed to the field by filling an identified research gap from thesis study 1 and provided preliminary prevalence estimates.

In summary, Study 1 laid the groundwork by identifying the research void concerning early childhood movement behaviours in SSA, while Study 2 took the critical next step by piloting practical methods to collect data within this context. Study 3 complemented these efforts by providing comparative evidence from other LMICs, which may offer findings more generalisable to SSA than existing research predominantly conducted in HICs. Collectively, these studies advance the broader aims of the thesis by contributing new knowledge on early childhood movement behaviours in SSA and building capacity for future large scale surveillance efforts across the region.

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2.4 Preamble references

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2. 5 Published article

As previously noted, this article was published as original research in the *African Journal for Physical Activity and Health Sciences (AJPHEs)* in December 2020. For ease of readability, the final proof-corrected Microsoft Word version of the manuscript is presented in the following section of this chapter, while the PDF of the published article, in its official journal format, is provided in **Appendix K** of this thesis.

Preschool children's compliance with the WHO 24-hour movement behaviour guidelines: A systematic review of sub-Saharan African studies

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Chapter 3: Twenty four hour movement behaviours in the early years in Tanzania: SUNRISE pilot study

3.1. Preamble

This chapter presents findings from the pilot implementation of the SUNRISE protocol in Tanzania. This study addresses critical knowledge gaps identified in chapter 2 (Nusurupia et al., 2020) regarding young children's compliance with the WHO 24-hour movement behaviour guidelines in SSA. Early childhood is recognised as a pivotal developmental period for establishing lifelong health behaviours (WHO, 2019), making it crucial to understand movement behaviours in contexts like Tanzania, where such research has been previously lacking.

3.2 Chapter context and findings

The study confirmed the feasibility of implementing the SUNRISE protocol in Tanzania, as reflected by high enrolment and completion rates across the various assessments. Feasibility studies assess the potential for successfully executing research as planned, by evaluating key elements such as recruitment processes, participant compliance, acceptability of procedures, and measurement tools (Bowen et al., 2009). To test how feasible the SUNRISE Study protocol was in many countries therefore, each participating country in the SUNRISE study was required to conduct a pilot study prior to implementing the full-scale study (Okely et al., 2021). In this present study feasibility was assessed whether recruitment, retention, data loss and protocol can be effectively implemented before scaling up. While feasibility criteria vary by study, they serve as valuable benchmarks for improving protocols and guiding future research (Eldridge et al., 2016).

A total of 152 invitation letters were distributed to parents across the eight selected nursery schools, without pre-filtering by exact age. Although the study focused on children under five, eligibility was confirmed at enrollment using a strict age criterion of 3.0 to 4.9 years.

At this point, 42 children were excluded for being 5 years or older (≥ 5.0 years). Consequently, 110 children met the eligibility criteria and were enrolled in the study. Of these, six children later withdrew from the study, with parental concerns about the use of accelerometers cited as the main reason for non-participation. This resulted in a final analytic sample of 104 children with valid data.

The study showed the practicality of employing accelerometers, with 65% of the recruited children providing valid data for at least three days. Furthermore, the study achieved a 95% enrolment rate among eligible participants, and 94% of parents completed the movement behaviour questionnaire. Preliminary assessments of compliance with the guideline revealed that 85% of children complied with the TPA guideline, while 94% complied with the MVPA guideline.

TPA and MVPA were conceptualised and reported as individual components and thus presented as separate guidelines. However, it is important to acknowledge that in much of the existing literature, TPA and MVPA are often integrated and treated as part of a single physical activity guideline. In such cases, the recommendation for MVPA is considered a subset within the broader TPA guideline, rather than a standalone guideline.

While 43% of the children complied with the screen time guideline, 63% complied with the sleep duration guideline and only 37% complied with the time spent in restrained sitting guideline. Further, just 23% of the children complied with all five guidelines in the present study, which included TPA, MVPA, screen time, sleep time, and restrained sitting time.

Statistically significant differences were observed between urban and rural children, with those in rural settings demonstrating higher levels of TPA, LPA, step counts, and longer sleep durations. In contrast, urban children spent more time in restrained sitting, which may be attributed to differences in transportation to day care centres and limited access to outdoor play areas. Most urban children travel to daycare using school buses, whereas their rural counterparts are more likely to walk.

The study also identified key feasibility challenges, including parental concerns regarding accelerometer use and difficulties in reattaching devices following water-based activities.

Overall, this pilot study underscores the feasibility of implementing a large-scale SUNRISE study in Tanzania. It demonstrates the practicality of the SUNRISE protocol and provides preliminary estimates of compliance with WHO movement behaviour guidelines among children aged 3 to 4 years. However, it is important to note that the movement behaviours of children attending ECEC programmes might differ from those of their non-enrolled peers (Mligo 2018). Children enrolled in ECEC may experience more structured daily routines, including scheduled play, learning activities, and rest periods, which can influence levels of physical activity, sedentary behaviour, and sleep (Tonge et al., 2016). In contrast, children who are not enrolled may spend more time in home or community environments where routines and opportunities for activity vary considerably.

This distinction is particularly relevant in the Tanzanian context, where early childhood education is not compulsory and participation are not universal (Mligo 2015). Access to ECEC programmes varies by region and socioeconomic status, with lower enrollment rates often observed in rural and disadvantaged communities (Nsamenang,2008). Consequently, the findings of this study should be interpreted with some caution, as the sample was drawn from children attending ECEC centres and may not fully represent the movement behaviours of all children aged 3–4 years in Tanzania. Future research should aim to include both children who attend early childhood education and care (ECEC) settings and those who do not and employ more representative sampling, to provide a more comprehensive understanding of movement behaviours within this population.

3.3 Contribution to this thesis

This study significantly contributes to the thesis by addressing a major research gap regarding early childhood movement behaviours in Tanzania. It offers important preliminary baseline data and suggests that the proposed methods for future large-scale studies are practical.

Importantly, it connects directly to the next phase of research presented in Chapter 4, where correlates of meeting guidelines including urban versus rural differences are explored in a broader LMIC context. Study 2 (pilot studies in Tanzania and other countries) not only informed study 3 by refining the methodological approaches (such as accelerometer use and questionnaire feasibility) but also provided foundational insights into key variables such as urban rural disparities that are critical to understanding movement behaviour differences globally. Furthermore, the findings highlighted the broader need for systematic surveillance of early childhood movement behaviours, a gap that persists not only in LMICs like Tanzania but also in many other HICs. This was supported by De Craemer et al. (2024) in their assessment of surveillance gaps for movement behaviours in 3–4 year olds across the WHO European Region. Together, these studies build a cohesive and progressive exploration of movement behaviours in early childhood, supporting the thesis's broader objectives of informing global public health strategies and surveillance frameworks.

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3.5 Published article

As previously noted, this article was published as original research in the *African Journal for Physical Activity and Health Sciences (AJPHES)* in December 2024. For ease of readability and to maintain consistency of formatting within the thesis, the final proof-corrected Microsoft Word version of the manuscript is presented in the following section of this chapter. The officially published version, in its journal PDF format, is included in **Appendix L** to provide a complete and accurate record of the publication

Twenty-four-hour movement behaviours in the early years in Tanzania: SUNRISE pilot study

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Chapter 4: Urban versus rural differences in meeting 24-h movement behaviour guidelines among 3–4 year olds: An analysis of SUNRISE pilot study data from 10 LMICs.

4.1 Preamble

This chapter examines the correlates of meeting the 24-hour movement behaviour guidelines among the 3 to 4 year old children in LMICs. While the published paper, *"Urban versus rural differences in meeting 24-hour movement behaviour guidelines among 3–4 year olds: An analysis of SUNRISE pilot study data from 10 LMICs"* (published in *Child: Care, Health and Development*, 2024), placed particular emphasis on urban rural differences, the broader aim of this study was to examine a range of correlates within LMICs.

At the time this study was designed, data availability from SSA was limited, which posed practical challenges for focusing solely on research questions about the correlates of movement behaviours/meeting movement behaviour guidelines in 3–4 year olds from SSA. Consequently, the scope of this research expanded to encompass LMICs more broadly. This strategic decision ensured the generation of more robust and comparable data, while still maintaining relevance to the SSA context.

Importantly, the study was guided by the BEF, which underpins this thesis, as described in chapter 1, emphasising the need to identify both prevalence and correlates of movement behaviours as foundational steps toward intervention development. In addition, the study was grounded in the socioecological model, allowing for the exploration of correlates across multiple levels, including individual, family, and broader environmental factors. This multi level approach enabled a more comprehensive understanding of the complex factors shaping young children's movement behaviours. Particular attention was given to urbanisation as a critical contextual factor in LMICs, including SSA, where rapid urban growth is likely to significantly affect children's movement behaviours. Accordingly, comparisons between urban and rural settings were included to capture potential differences and better inform context-sensitive strategies for promoting healthy movement behaviours in future.

4.2 Chapter context and findings

The WHO introduced the 24-hour movement behaviour guidelines for 3 to 4 year old children in 2019 as described in chapter 1, emphasising the importance of physical activity, reduced sedentary time, and sufficient sleep for optimal health and development (WHO, 2019). Despite the importance of these guidelines, compliance among young children might be low. Furthermore, it is currently unclear whether there are notable differences in compliance between children from urban and rural settings in LMICs (Okely et al., 2021). This lack of evidence creates a critical gap in understanding children's movement behaviours within these regions. The SUNRISE study was initiated to assess children aged 3 to 4 years who are complying with WHO guidelines and to identify variations based on age, sex, parent education, and settings (<http://www.sunrise-study.com>; Okely et al., 2021) as summarised in chapter 1.

No statistically significant differences were observed in the proportion of children meeting the 24-hour behaviour guidelines between urban and rural settings after controlling for sex, age and socioeconomic status. Overall, 17% of children met the physical activity component of the guidelines (14% in urban areas vs. 18% in rural areas). It is not clear whether a physical activity transition has yet occurred in this context, however, TPA levels in both rural and urban settings are relatively low. The limited differences observed in this study between rural and urban children may be attributed to several factors. Historically, rural areas were linked to higher levels of physical activity due to labour-intensive livelihoods, limited motorised transport, and more opportunities for outdoor play, whereas urban areas often promoted more sedentary behaviour (Muthuri et al., 2014). However, in many LMICs, these distinctions have diminished over time (Swindell et al., 2022). Additionally, changes in socioeconomic conditions, education, and caregiving practices may have further reduced the contrasts in children's daily routines between rural and urban settings. Consequently, the rural–urban gap in 24-hour movement behaviours may now be narrower than in previous decades, reflecting the early stages of the physical activity transition, where declining activity and increasing sedentary behaviour occur across both rural and urban populations (Muthuri et al., 2014; Katzmarzyk & Mason, 2009). Finally, because the present study was based on pilot data from selected LMICs with available secondary data, future research using larger and more representative samples from each country, such as the SUNRISE main studies, would be useful to determine the generalisability of these findings.

Finally, since the present study was based on pilot studies from selected LMICs (those with data available for secondary analysis at the time), future studies with larger and more representative samples from each country (e.g. SUNRISE main studies) would be useful to test if findings of the present study are generalisable.

4.3 Contribution to this thesis

This study makes a significant contribution to the overall thesis by expanding the investigation of early childhood movement behaviours from a narrow regional focus on SSA to a broader LMICs context. When this study was designed, the availability of data from SSA was extremely limited, posing a practical constraint. Recognising this, the study strategically incorporated LMICs more broadly to ensure the generation of robust and generalisable evidence, while still maintaining relevance to SSA settings.

In the current study, the activPAL device was used, while Study 2 employed the ActiGraph. It is noteworthy that what is now referred to as Study 2 and Study 3 were initially planned in reverse order. During the implementation phase of the SUNRISE Protocol Phase II, the study now known as Study 2 (originally conceived as Study 3) utilised both the ActiGraph and activPAL devices simultaneously. However, due to practical challenges and subsequent protocol modifications, the ActiGraph was retained as the sole device, leading to the discontinuation of the activPAL. As a result, Study 2 proceeded with the updated protocol using only the ActiGraph. However, it is important to consider the differences in device usage when interpreting the findings. Both activPAL and ActiGraph devices are recognised as valid and reliable tools for assessing physical activity, sedentary behaviour, and sleep in children aged 3–4 years (Martin et al., 2011). But, due to variations in measurement approaches and data processing methods, the estimates derived from each device are not directly comparable. This should be considered when making comparisons across studies.

This chapter builds directly upon the findings of study 1 (Chapter 2), which systematically reviewed the limited evidence on young children's movement behaviours in SSA and highlighted significant knowledge gaps. While study 1 underscored the urgent need for region specific surveillance among 3–4 year olds, the present study expands the geographical scope to a broader range of LMICs.

Using standardised methodologies, it examines the prevalence of compliance with movement behaviour guidelines and explores key potential correlates, including socioeconomic status, age, sex, and urban versus rural residence. Recognising the influence of urbanisation particularly in LMICs experiencing rapid social and environmental changes was a central focus of the analysis. Additionally, this study closely aligns with study 2 (Chapter 3), the SUNRISE pilot conducted in Tanzania. The pilot study established the feasibility of employing standardised protocols, such as accelerometer and parent reported questionnaires, to collect high-quality data on movement behaviour prevalence and correlates. The pilot study provided practical insights and contextual understanding such as the relevance of urbanisation, which were later examined across multiple LMICs in the present study. Overall, this chapter strengthens the thesis by providing evidence on the prevalence and correlates of 24-hour movement behaviours across diverse LMIC settings, highlighting the growing need for surveillance and targeted interventions, and reinforcing the importance of environmental and sociodemographic factors such as urbanisation in shaping young children's health behaviours.

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4.5 Published article

As previously noted, this article was published as original research in the Child: Care, Health and Development journal in 2024. For ease of readability and to maintain consistency of formatting within the thesis, the final proof-corrected Microsoft Word version of the manuscript is presented in the following section of this chapter. The officially published version, in its journal PDF format, is included in **Appendix M** to provide a complete and accurate record of the publication.

Urban Versus Rural Differences in Meeting 24- h Movement Behaviour Guidelines Among 3–4- Year- Olds: An Analysis of SUNRISE Pilot Study Data From 10 Low- and Middle- Income Countries

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Abstract

Background: Insufficient physical activity, excessive screen time, and short sleep duration among young children are global public health concerns, however, data on prevalence of meeting World Health Organization 24-hour movement behaviour guidelines for 3–4-year olds children in low- and middle-income countries (LMICs) are limited, and it is unknown whether urbanisation is related to young children's movement behaviours. The present study examined differences in prevalence of meeting 24-hour movement behaviour guidelines among 3–4-year old children living in urban vs rural settings in LMICs.

Methods: The SUNRISE study recruited 429, 3–4-year old child/parent dyads from 10 LMICs. The children wore activPALTM accelerometers continuously for at least 48 hours to assess their physical activity and sleep duration. Screen time and time spent restrained were assessed via parent questionnaire. Differences in prevalence of meeting guidelines between urban and rural dwelling children were examined using chi-square tests.

Results: Physical activity guidelines were met by 17% of children (14% urban vs 18% rural), sleep guidelines by 57% (61% urban vs 54% rural), screen time guidelines by 50% (50% urban vs 50% rural), restrained guidelines by 84% (81% urban vs 86 % rural), and all guidelines combined by 4% (4% urban vs 4% rural). We found no significant differences in meeting the guidelines between urban and rural areas.

Conclusions: Only a small proportion of children in both rural and urban settings met the WHO 24-hour movement guidelines. Strategies to improve movement behaviours in LMICs should consider including both rural and urban settings.

Keywords: Preschool children, physical activity, sleep, 24-hour, movement behaviours, LMICs.

Background

Time spent in physical activity, sedentary behaviours (including screen time), and sleep (the 24-hour movement behaviours) are crucial to health and development in early life¹. During the launch of the World Health Organisation (WHO) guidelines on physical activity, sedentary behaviour, and sleep for under-5s in 2019¹, the WHO Director General Dr. Tedros Adhanom Ghebreyesus said that 'Early childhood is a period of rapid development when family lifestyles can be adapted to boost health gains'. Improving physical activity, reducing sedentary time, and ensuring adequate sleep among young children can improve their physical and mental health in the short- and long term, and help to prevent obesity and associated diseases¹. Obesity can affect the immediate and long-term health of a child, educational attainment, and quality of life.²

The WHO guidelines¹ recommended that children aged 3–4 years, in a period of 24 hours, should: (i) spend 180 minutes in physical activity (of which at least 60 minutes should be moderate- to vigorous-intensity physical activity, MVPA) ; (ii) not be restrained for more than an hour at a time; (iii) not engage in more than one hour of sedentary screen time; and (iv) have 10–13 hours of good quality sleep. To date, various countries have developed, adopted, or adapted guidelines for the early years to fit their socio-economic and cultural circumstances. Canada was the first country to develop combined/integrated 24-hour movement behaviour guidelines for the early years in 2017³. This was soon followed by Australia⁴ and New Zealand⁵. The United Kingdom (UK) guideline development group recommended that 24-hour movement behaviour guidelines be adopted for the under-5s, but the UK Health Departments only adopted the guidelines for total physical activity (TPA) and MVPA⁶. Among LMICs, South Africa⁷ and Thailand⁸ have also developed 24-hour movement behaviour guidelines for the under 5s.

Since the release of the WHO 24-hour movement guidelines for under 5s in 2019¹, research has shown that the prevalence of children meeting these guidelines may be low. For example, a study from Canada⁹ found that only 13% of preschool aged children met the 24-hour movement behaviour guidelines, and only around 14% of from Australia¹⁰. Nevertheless, since most of these studies on the prevalence of meeting the WHO movement behaviour guidelines for 3–4-year olds were retrospective, i.e., not specifically designed to answer research questions about prevalence, it is possible that studies designed to estimate prevalence and differences in prevalence (e.g. between urban and

rural dwelling children) might produce different results. In addition, most of these studies were conducted in high-income countries (HICs) and very few studies have been conducted in LMICs. For example, in a recent systematic review and meta-analysis of children under 5 years of age¹¹ only 1 study out of 11 was conducted in LMICs. More recently, some LMICs have begun to conduct research in this area following the development of the International Study of Movement Behaviour in Early Years (SUNRISE)¹². SUNRISE was developed with the major aim of determining the proportion of preschool children (3–4-year olds) meeting the WHO 24-hour movement behaviour guidelines for the early years and identifying differences in prevalence of meeting guidelines by factor such as age, sex, and urban vs rural living¹².

The Behavioural Epidemiology Framework¹³ presents a conceptual basis for studying prevalence and correlates of health behaviours (e.g., meeting health behaviour guidelines), so that interventions aimed at improving health behaviours can be developed. This framework notes the importance of identifying if health behaviour guidelines are typically being met or not and emphasises the need to determine which risk factors (e.g., socio-environmental factors such as sex, age, season, socio-economic status) are related to not meeting guidelines¹³. Evidence on the correlates of meeting or not meeting the WHO guidelines will help in determining high-risk groups and provide guidance on how to equitably promote healthier levels of physical activity, sedentary behaviour, and sleep in early childhood. At present, it is unclear whether there are marked differences in meeting the 24-hour movement behaviour guidelines between children from urban vs rural environments in LMICs¹². In sub-Saharan Africa for example, our previous systematic review found negligible evidence on time spent in the movement behaviours in young children from both urban and rural settings¹⁴. Some studies^{15,16,17} in LMICs have found differences in physical activity between school-age children and adolescents living in urban and rural settings but whether such differences exist at younger ages, and whether they apply to the other movement behaviours, is unknown. Therefore, the aim of the present study was to examine in an international cross-sectional study whether urban versus rural living location was associated with the probability of meeting the WHO movement behaviour guidelines in LMICs.

Methods

Study setting

This study used data from 10 countries classified as LMICs based on their economic status using World Bank categories¹⁸. Participants in the present study were recruited as part of the first and second pilot phases of the SUNRISE study^{12,19}. To participate, children needed to be between the ages of 3.0 and 4.9 years and to be in apparently good health, children with disabilities or other chronic diseases were excluded. In each of the participating SUNRISE countries, a pilot study took place with the aim of recruiting approximately 100 children, with approximately equal numbers of boys and girls and equal numbers from urban and rural settings. Participating countries in the current study were all the SUNRISE LMICs that had completed their feasibility study and used activPAL™ monitors (manufacturer, location) prior to the COVID-19 pandemic in 2020. The countries included were Bangladesh (lower middle income), Zimbabwe (lower middle income), Vietnam (lower middle income), Sri-Lanka (lower middle income), Indonesia (lower middle income), Papua New Guinea (lower middle income), Brazil (upper middle income), China (upper middle income), Malaysia (upper middle income), and South Africa (upper middle income)¹⁸. The SUNRISE protocol demonstrated a high¹² level of feasibility and hence pilot study data were combined for the present secondary analysis.

Measurements of physical activity and sleep

activePAL™ accelerometers were used to objectively assess the child's time spent asleep, in physical activity, and time spent sedentary. The activPAL is currently the only single device which permits measurement of time spent in all of these movement behaviours. The use of activPAL™ accelerometers in the SUNRISE study was based on their high reliability and validity for measurement of posture allocation (i.e., lying, sitting, standing) and time spent in physical activity in preschool children²⁰. There are, however, inconsistent results when it comes to the practical utility of the activPAL in children aged 3-4: with some showing better compliance than others and a study of high validity for TPA and MVPA, but for an older model of activPAL. It is therefore unclear how accurate the activPAL model used for MVPA is but have not found studies suggesting low accuracy for TPA among 3-4-year olds.

Children were asked to wear the activPAL™ on their right thigh for five days to get at least two full valid days (a valid day was defined as having 24-hours of valid data with a minimum of 6 hours of valid wear time during waking hours) of data. An output file (event file) was created using the PAL batch software (v8.10: PAL Technologies Ltd, Glasgow) and standard PAL analysis algorithm (VANE). Full details of measurement procedures are available in the SUNRISE study protocol paper¹² and website¹⁹.

Time spent moving (referred to as 'stepping' in activPAL™ output), referred to as TPA from here onwards because it provides a valid measure of total physical activity in 3–4-year old children²⁰ and time spent sleeping were calculated via a custom-made MATLAB program. This version of the activPAL™ has not yet been validated for measurement of MVPA and so time spent in MVPA data were not used in the present study. Total physical activity and sleep time were calculated for each day and then averaged across all valid days for each child. Children were categorised as meeting the total physical activity guideline if they had at least 180 minutes of TPA averaged over all included days. Children who spent an average of 10- to 13-hours sleeping were classified as meeting the sleep guidelines. Total daily step counts were also measured by activPAL™ as these provide a valid proxy measure of meeting (at least 11,500 steps/day) or not meeting (less than 11,500 steps/day) the WHO guideline for total time spent in physical activity in 3-to-4-year olds²¹.

Measurement of screen time and restrained sitting

Parents were asked to complete a questionnaire reporting the total time their child spent using digital screens per day (minutes/day)¹³. Parents were also asked to report when their child was restrained for more than 1 hour at a time (e.g., in a car seat or stroller)¹³. Children were categorised as meeting the screen time guideline if they spent ≤ 60 minutes 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.

Urban vs rural environment

For categorisation of rural/urban setting, each country provided its own definition as there is no global definition of urban versus rural setting.

Based on each country's classification, we then dichotomised the samples as urban or rural¹³ and combined the data to make an urban group and rural group as shown in Supplementary File 1, **table 4-3**. Several control variables were captured through the parental questionnaire in the SUNRISE study¹³ including age, sex, and socio-economic status (SES). SES was derived from parental education level, dichotomised as high (completed higher education) and low (secondary/high school or below) or high (tertiary education or above) education as control variables. The SUNRISE study parent questionnaire was based on a modified version of the WHO STEPwise approach to surveillance (STEPS) questionnaire.^{22,12.}

Statistical analysis

All statistical analyses were conducted using SPSS version ²⁸. Participant characteristics are presented using descriptive data analysis, means (SDs), or frequencies (percentages) as appropriate. Chi-square test (χ^2) (categorical variables) and unpaired t-tests (continuous variables) were used to examine potential differences between children in urban and rural settings. A significant association was defined as a p value of <0.05 for independent sample tests. Using univariate ANOVAs, means were compared between urban and rural settings while controlling for sex, age, and SES. Dependent variables were movement behaviours (total sitting time, total standing time, total physical activity, total steps taken, total sleep time and total screen time).

Results

Characteristics of study participants

Out of 497 children who participated in the present study, 429 (86%) had completed two days (i.e., 2 x 24h periods) of accelerometer data for analysis. **Table 4-1**. shows the descriptive characteristics of the sample. The mean age was 4.3 (0.4) years, 218 boys (51%), and 222 of the parents had high SES (52%). Out of the 429 children, 235 were living in rural areas (55%). Furthermore, Appendix 1, **table 4-3** provides descriptive characteristics of 497 children who had completed one day's worth of accelerometer data for analysis (i.e., 1 x 24h periods).

Meeting individual movement behaviour guidelines in urban and rural settings

Table 4-2. shows the percentage of children meeting and not meeting the guidelines in urban and rural settings. No significant differences were found in the prevalence of meeting any of the movement guidelines between urban and rural participants.

A comparison of continuous variables using univariate analysis of variance

Sitting time was significantly related to urban/rural living after controlling for sex, age, and SES; children in urban settings sat for a longer period of time than those in urban settings ($F(1, 392) = 4.94, p=0.027$).

There was no significant difference between settings for total standing time ($F(1, 392) = 0.622, p=0.431$), TPA ($F(1, 392) = 1.554, p=0.213$), total steps taken ($F(1, 392) = 2.068, p=0.151$), time spent in sleep ($F(1, 392) = 1.033, p=0.310$), or screen time ($F(1, 383) = 0.402, p=0.526$), after controlling for sex, age, and SES.

Discussion

Main Findings

This study aimed to investigate whether setting (urban vs rural) was associated with meeting the WHO 2019 movement behaviour guidelines in 3–4-year olds from LMICs. We found that the majority of children from LMICs did not meet WHO 24-hour movement guidelines, and urban versus rural differences in prevalence of meeting guidelines were small. The present study suggests that not meeting the movement behaviour guidelines might be common among young children in many LMICs, even in rural settings. If confirmed by larger future studies then research and surveillance with young children in 3–4-year olds globally might need to have more of a focus on rural settings.

What is already known on this topic?

Health and development are profoundly impacted by movement behaviours during the early years^{1, 12} but the published evidence comes mostly from HICs^{23,24} and there is a dearth of evidence on urban rural differences in the movement behaviours in LMICs.

What this study adds

Prevalence of meeting 24-hour movement behaviour guidelines was low and did not differ markedly between urban and rural settings. Despite perceptions that young children are naturally active²⁵ children in both urban and rural settings in the present study had low physical activity and spent a substantial amount of their waking hours sedentary. The results are consistent with findings from high-income countries^{26,27} that excessive screen time is prevalent among 3–4-year olds and this is a concern for health and development^{28,29}.

It has been suggested that differences in the time spent in movement behaviours between urban and rural school-age children and adolescents could be attributed to differences in the physical environment, air pollution, and housing units in sub-Saharan Africa^{30,31}. From the present study findings, it is unclear why there were negligible differences in movement behaviours between rural and urban settings in 3-4-year olds. This similarity might be due to the physical activity transition, which is characterised by declining physical activity and increasing sedentary time as countries experience economic development. The present study suggests the possibility that the physical activity transition has now occurred in both urban and rural settings of the LMICs included in the present study, and so smaller differences between urban and rural settings were observed than would have been typical prior to the transition^{32,33}.

In global movement behaviour surveillance, rural populations are under-represented, especially in LMICs³⁴. This may be due to logistical difficulties involved in conducting surveillance in rural areas as well as the assumption that urban areas have more problems with movement behaviours than rural areas. The present study is consistent with previous criticism³⁵ that future surveillance of movement behaviours should consider both rural and urban settings. A more comprehensive understanding of movement behaviour differences between population groups will help LMICs improve their public health policies and interventions to cope with the NCD crisis and the physical activity transition.

Strength and limitations of the present study

There are several strengths of the present study. First, it was a novel study in LMICs as noted above. Second, the present study used the SUNRISE protocol, which has proven practical and culturally appropriate for LMICs, and movement behaviours were objectively measured with the same device wherever possible¹².

Third, most previous studies focused on individual movement behaviours, while the present study included all of the movement behaviours, with objective measurement of time spent in physical activity, sedentary behaviour, and sleep. Finally, a novel aspect of the study was the comparison between rural and urban settings in early childhood and in LMICs.

However, the present study had some limitations that should also be noted. First, convenience sampling was sufficient to test for urban versus rural differences in movement behaviours, but more representative samples will be required to obtain more precise estimates of prevalence of meeting movement behaviour guidelines - the SUNRISE 'main studies'¹² are intended to do just that in future. Second, despite the device-measured time spent in physical activity and sleep were major strengths, some variables can only be measured by parent proxy reports at the moment (screen time, restrained time) and there was no alternative method.

The present study was not powered to make comparisons between two groups (i.e. children living in rural and urban settings) but will assist future power calculations and suggests that differences might be small. Further larger studies will be needed to confirm our findings but also to examine the reasons for any differences or lack of differences between urban and rural settings. The SUNRISE Study¹² –funding permitting- will move on to larger scale studies which test for urban and rural differences more definitively across a range of different LMICs. Finally, the activPal model used in the present study provides valid measures of TPA²⁰ but has not yet been validated for measurement of moderate-to-vigorous intensity physical activity (MVPA) in this age group, but the low levels of TPA observed in the present study suggest that levels of MVPA were probably also low.

Conclusion

Only a small proportion of LMIC children who lived in both rural and urban settings met the individual and combined movement guidelines in the present study. The present study suggests that there is a need to include both rural and urban settings in future public health surveillance of the movement behaviours, and in mitigation strategies for the physical activity transition in LMICs.

Authors Contributions

Jackline J, Nusurupia: Substantial contribution to conception and design, analysis and interpretation of data, drafting the article, and final approval of the version to be published.

Leyna H. Germana: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Pujitha Wickramasinghe: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Hong K. Tang: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Nyaradzai Munambah: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Mohammad S. Hossain: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

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Guan Hongyan: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Alex A. Florindo: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Catherine E. Draper: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Denise Koh: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Kuston Sultoni: Substantial contribution to data acquisition, revising article critically for important intellectual content, and final approval of the version to be published.

Adang Suherman: Substantial contribution to data acquisition, drafting the article or revising it critically for important intellectual content, and final approval of the version to be published.

Anthony D. Okely: Substantial contribution to conception and design of the study, drafting the article or revising it critically for important intellectual content, and final approval of the version to be published.

Mark S. Tremblay: Substantial contribution to conception and design of the study, drafting the article or revising it critically for important intellectual content, and final approval of the version to be published.

Xanne Janssen: Substantial contribution to conception and design, analysis and interpretation of data, revising article critically for important intellectual content, and final approval of the version to be published.

John J Reilly: Substantial contribution to conception and design, interpretation of data, revising article critically for important intellectual content, and final approval of the version to be published.

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Declaration of conflict of interest

The authors declare that they have no competing interests.

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Data availability

The data that support the findings of this study are available from the SUNRISE team upon reasonable request.

Ethical approval

Ethical approval was obtained from the University of Wollongong, Australia (ref: 2018/044) and in each individual participating country through local ethical review authorities. Parents/guardians provided informed consent for their child's participation in each country.

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Table 4-1: Descriptive characteristics Mean (SD)

Variables	All (n=429)	Urban (n=194)	Rural (n=235)	P-Value
Age Years	4.3 (0.4)	4.3 (0.4)	4.4 (0.4)	0.005
Sex boys %(n)	51 (218)	55 (106)	48 (112)	0.174
Socio Economic Status high % (n)	56 (222)	42 (76)	68 (146)	<0.001
Total sitting time minutes/day	442 (96)	459 (92)	429 (98)	0.001
Total standing time minutes/day	210 (59)	205 (59)	216 (58)	0.057
Total physical activity minutes/day	137 (52)	132 (52)	142 (52)	0.050
Total steps /day	110338 (4425)	9830 (4281)	10757 (4506)	0.031
Total sleep time minutes/day	649 (97)	644 (83)	654 (106)	0.322
Screen time minutes/day b	104 (94)	104 (91)	104 (96)	0.997

aSES was measured using the level of parental education an=397, bn = 419, cp-value for independent t-test or chi-square,

SD= standard deviation.

Table 4-2: Prevalence of meeting the guidelines in rural and urban areas % (n)

Variables	Total meeting guideline for both settings (n=429)	Urban (n=194)	Rural (n=235)	p-value
Meeting the total physical activity guideline	17 (71)	14 (28)	18% (43)	0.284
Meeting sleep guideline	57 (244)	61 (118)	54 (126)	0.134
^a Meeting screen time guideline	50 (211)	50 (96)	50 (115)	0.971
Meeting restrained guideline	84 (359)	81 (157)	86 (202)	0.161
^a Meeting all the guidelines	4 (17)	4 (7)	4 (10)	0.709

^an=419; value for chi-square

SUPPLEMENTARY FILES

Table 4-3: Definition of Rural/urban per each country

S/N	Country	How urban setting was defined	How rural setting was defined
1	South Africa	Formal metropolitan area, that include “townships” which include formal and informal housing (e.g., shacks).	Consists of villages, traditional leadership and communal land ownership (former “homelands” under apartheid).
2	Zimbabwe	Region surrounding the city, there is density of human structures such as houses, commercial buildings, roads, bridges, and the area is developed – has roads, electricity and tap water.	Region located far away from city or town. Households are sparsely populated.
3	Malaysia Definition based on 2010 Population and Housing Census. (Reference: department of Statistics Malaysia, 2010)	Gazetted areas with their adjoining built-up areas which have a combined population of 10,000 or more. Built-up areas were defined as areas contiguous to a gazetted area and had at least 60 per cent of their population (aged 15 years and over) engaged in non-agricultural activities.	All other gazetted areas with population of less than 10,000 persons and non-gazetted areas.
4	Vietnam	Urban is an area where living residents concentrate with high density and operate primarily in non-agriculture economy, the center of politics, administration, economy, culture or profession, with the role of promoting economic and social development of the country or a region of territory or a locality, including the inner city, suburbs of the city, inner town and outskirts of towns, and townships. Source: Decree No. 42/2009/ND-CP (Vietnam Government, 2009).	Rural can be defined as an area without indicators to be considered urban. According to Decree No. 57/2018/ND-CP, a “rural area refers to an administrative division, excluding areas situated in the vicinity of award of a district-level town, district, or city” (Vietnam Government, 2018).
5	Sri-Lanka	Based on the local government division into urban councils and divisional councils. It is based on geo-economic factors of the area.	Based on the local government division into urban councils and divisional councils. It is based on geo-economic factors of the area.

6	Brazil	São Paulo city, 1 school, Sao Paulo State (Defined by municipal government).	Itatiba city, 1 school, Sao Paulo State (Defined by municipal government).
7	Bangladesh	Three schools participated in the greater metropolitan area of Dhaka.	Two schools were included in a rural-like setting from less-developed part of Dhaka).
8	Papua New Guinea	Urban rural setting was defined according to the National Statistics Office of Papua New Guinea, aligned with the urban rural classification of the National Census 2020.	The urban and rural sites which were selected for conducting SUNRISE study were about 30 km away from each other or about one hour drive.
9	Indonesia The classification Based on the Regulation of the head of BPS-statistics Indonesia No. 37 Of 2010 Regarding the classification of urban and rural areas in Indonesia. (Reference: BPS – Statistics Indonesia, 2010).	Urban areas are defined as regions meeting specific criteria including population density, percentage of agricultural, households and access to urban facilities, with a combined total score of 10 or higher (BPS-Statistics Indonesia,2010). Eight early education centres in Bandung City participated.	Rural areas are defined as regions meeting specific Criteria including population density, percentage of Agricultural households, and access to urban facilities, resulting in a total score below 10 (BPS – Statistics Indonesia, 2010). Seven early education centres in District of Ciamis participated.
10	China	Based mainly on the hig.h population density, social-economic indicators where there is no agriculture, and people usually live in the high-rise apartment.	Based mainly on the low population density and socio economic status, where the agriculture is one of important resources of family income Usually, the rural place is called as township level, or village level. And People usually live in low-rise apartment or house.

Table 4-4: Descriptive characteristics of 497 children who had completed one day's worth of accelerometer data for analysis (i.e., 1 x 24h periods).

Descriptive characteristics Mean (SD)

Variables	All (n=497)	Urban (n=227)	Rural (n=270)	P-Value
Age Years	4.3 (0.4)	4.3 (0.4)	4.4 (0.4)	0.003
Sex boys %(n)	51 (254)	54 (122)	49 (132)	0.281
Socio Economic Status high% (n)	42 (209)	58(132)	29 (77)	<0.001
Total sitting time minutes/day	442 (101)	452(96)	434(104)	0.051
Total standing time minutes/day	208 (60)	201 (61)	214 (59)	0.016
Total physical activity minutes/day	137 (53)	131 (52)	142 (54)	0.015
Total steps taken/day	10338 (4495)	9755(4226)	10828 (4660)	0.008
Total sleep time minutes/day	653 (104)	657 (99)	650(108)	0.459
Screen time minutes/day	105 (96)	103 (94)	106 (98)	0.672

aSES was measured using the level of parental education bp-value for independent t-test or chi-square, SD= standard deviation.

Chapter 5: Overall thesis discussion and conclusions

5.1 Introduction

The current thesis examines the 24-hour movement behaviours, including physical activity, sedentary behaviour, and sleep, among children aged 3 to 4 years. While focusing primarily on Tanzania, the thesis situates its findings within the broader contexts of SSA and other LMICs. It consists of three interrelated studies designed to identify and address significant gaps in evidence regarding the prevalence, measurement methods, and contextual correlates of these behaviours in under researched settings like Tanzania.

To address the main purposes of this thesis, specific objectives were developed across the three studies as highlighted below:

- Study 1 (Chapter 2) presents a systematic review synthesising existing research on compliance with the WHO 24-hour movement guidelines among 3–4 year olds in SSA (Nusurupia et al., 2020). The review highlights a considerable scarcity of region-specific data, identifying areas needing further research.
- Study 2 (Chapter 3) serves as a pilot for implementing the SUNRISE international study protocol (Nusurupia et al., 2024). Its primary objectives include evaluating the feasibility of the proposed methodologies for a larger scale study and providing preliminary estimates of compliance with WHO (2019) guidelines among Tanzanian children aged 3 to 4 years.
- Study 3 (Chapter 4) examines the correlates of meeting the WHO movement behaviour guidelines in a cross-sectional sample of 3- to 4-year-old children from various LMICs, with particular attention to urban–rural differences, and identified potential correlates that are related to complying or not complying with the guidelines (Nusurupia et al., 2024).

This chapter synthesises and interprets the findings from these three thesis studies, contextualising them within the existing global literature, including some key studies published towards the end of the PhD, and discussing the implications for public health. Given the limited availability of comparative data, specifically from low-income SSA countries, the discussion draws primarily from recent studies and global analyses where applicable.

5.2 Key recent publications

Throughout this PhD research, which began in 2019, several important publications have emerged, enriching understanding of the broader evidence base on 24-hour movement behaviours among young children in sub-Saharan Africa (SSA). This section provides a concise overview of recent studies and situates the current thesis within this evolving body of research. Although many studies report broadly similar findings regarding the prevalence of children meeting movement behaviour guidelines in SSA, meaningful comparisons remain challenging due to substantial heterogeneity in study design, sample size, objectives (e.g., pilot versus larger scale prevalence-focused studies), sampling strategies, measurement techniques, and the number and combination of guideline components assessed.

Several SUNRISE pilot studies conducted across SSA (Draper et al., 2020; Munambah et al., 2021; Ltifi et al., 2023; Oginni et al., 2025) represent an important step toward addressing the limited evidence base in early childhood within the region. However, many were based on relatively small samples, which may limit statistical power and generalisability. Among these, studies from Ethiopia (Abdeta et al., 2024; $n = 430$) and Malawi (Mwase-Vuma et al., 2024; $n = 417$) included larger samples, providing more stable prevalence estimates and contributing more substantially to regional representation.

Despite these advances, methodological differences continue to constrain direct comparisons. A more comparable example is the SUNRISE Malawi study and Study 2 of this thesis, as both assessed four components of the WHO 24-hour movement guidelines: total physical activity (TPA), sedentary screen time, restrained sitting, and sleep duration. While both studies used ActiGraph accelerometers to measure physical activity, TPA was operationalised differently. The Malawi study defined compliance using step counts, reflecting overall movement without distinguishing intensity, whereas the Tanzanian study combined accelerometer-derived TPA and moderate-to-vigorous physical activity (MVPA). The remaining behaviours were assessed using parent-reported questionnaires in both studies. These methodological differences, alongside variation in compliance with individual behaviours, likely explain discrepancies in overall compliance. For example, higher compliance across all behaviours in Malawi (98% physical activity, 79% sedentary behaviour, 91% sleep, and 76% restrained sitting) compared to Tanzania (85%, 43%, 63%, and 37%, respectively) contributed to higher overall compliance (60% vs. 21%).

These differences may also reflect contextual factors, within the SEM, including socioeconomic conditions, urbanisation, cultural norms around child-rearing, and access to early childhood education. Consideration of both methodological and contextual influences is therefore essential for interpreting prevalence estimates and informing appropriate interventions.

It is important to recognise the methodological discrepancies that complicate direct comparisons of findings. One key source of discrepancies lies in how TPA and MVPA are operationalised across studies. Even when using the same measurement methods, some studies define meeting with physical activity guidelines as meeting both the MVPA and TPA components together, whereas others assess meeting MVPA and TPA as separate components. Additionally, some studies measure only MVPA, which further limits the comparability of prevalence estimates across studies.

An additional challenge relates to inconsistent terminology and age classification. The term “preschool” is not universally defined and may refer to different age ranges across settings. In some studies, it includes children up to 5 or 6 years of age, particularly those not yet in formal schooling (Feng et al., 2021). In contrast, this thesis focuses specifically on children aged 3–4 years. Such variation is important, as movement behaviours differ substantially with age, and broader age groupings may obscure meaningful differences and limit comparability across studies.

Further inconsistencies arise in how guideline components are assessed and reported. While the WHO framework includes three core domains (physical activity, sedentary behaviour, and sleep), not all studies measure or report all components, particularly restrained sitting. Some studies also expand definitions; for example, the Tunisian study (Ltifi et al., 2024) reported compliance across five indicators (MVPA, TPA, combined TPA and MVPA, screen time, and sleep duration). These variations further complicate cross-study comparisons.

To strengthen the evidence base, future research including the SUNRISE main study should prioritise standardised measurement and reporting protocols and clearly define compliance criteria (e.g., number and type of guideline components included). Greater consistency would enable more meaningful comparisons across countries and improve the applicability of findings in diverse LMICs settings.

Finally, Study 3 (Chapter 4) identified several correlates of compliance with the WHO 24-hour movement behaviour guidelines. No significant association was observed between residential setting and overall compliance, suggesting that shifts toward more sedentary lifestyles may be occurring in both urban and rural areas. This could indicate a narrowing of previously observed urban–rural differences in older children (Muthuri et al., 2014; Katzmarzyk & Mason, 2009). However, contrasting findings from Ethiopia (Abdeta et al., 2024) and Malawi (Mwase-Vuma et al., 2025) show higher compliance among rural children, indicating that such disparities may persist in some contexts and require further investigation.

5:3 Reflection on the Socioecological Model in the Context of this Thesis

Although SEM was discussed as a guiding theoretical framework in Chapter 1 section 1.13, its application in the current thesis has been more implicit than explicit. This finding is partly attributable to the current state of the evidence base and the scope of the studies included.

The first study presented in chapter 2, a systematic review, highlighted a notable gap in the literature, with little to no evidence examining correlates of 24-hour movement behaviours in young children from a socio-ecological perspective in SSA. In particular, no studies were examined compliance with movement behaviour guidelines within such a framework. This lack of evidence underscores the limited application of the SEM in this field within SSA setting.

The second study presented in chapter 3, the Tanzanian pilot study was not designed, nor sufficiently powered, to examine correlates of movement behaviours across the different levels of the SEM. Its primary aim was to assess feasibility and inform the design of a larger study. Nevertheless, as part of the SUNRISE protocol, a range of correlates were collected that align with multiple levels of the SEM, including individual (e.g., child’s age, sex), interpersonal (e.g., parent’s level of education), and environmental factors (urban vs. rural settings). These variables provide a valuable foundation for future analyses of the influence of multiple levels of the SEM in a larger, adequately powered, SUNRISE Tanzania main study.

The third study presented in chapter 4, the cross-country analysis of LMIC pilot data included a number of correlates that extend beyond individual-level factors, capturing aspects of the broader social and environmental context. While not explicitly framed using the SEM, these variables reflect elements of the model and demonstrate the feasibility of examining multilevel

influences on movement behaviours within LMIC settings.

Taken together, these findings suggest that while the SEM was not fully operationalised within the current thesis, it remains a relevant and important framework for guiding future research (Eriksson et al.,2025). In particular, future studies examining correlates and determinants of 24-hour movement behaviours in young children should adopt a more explicit social ecological approach, incorporating variables across multiple levels of influence (Golden & Earp, 2012). Furthermore, as research progresses along later stages of the BEF, the SEM provides a useful basis for the development of interventions that target not only individual behaviours but also the broader social, environmental, and policy contexts in which these behaviours occur.

5:4 Recent key evidence highlights the importance of examined compliance in children aged 3 to 4 years

The emerging "Next Thousand Days" paradigm expands the focus of early intervention to improve child health and development beyond the traditional first 1,000 days of life (from conception to age two) to include ages 3-4 years. This approach recognises the continued importance of ECD in shaping long-term health and developmental outcomes (Draper et al., 2024). Increasingly, the period between ages 2 and 4 has been acknowledged as a critical window for influencing movement behaviours and preventing childhood obesity (WHO, 2019). This developmental stage offers a strategic opportunity for enhanced surveillance and intervention, particularly through Early Childhood Education and Care Services (ECECS), which are increasingly recognised as vital platforms for public health engagement (WHO, 2021). When aligned with international frameworks, such as the WHO guidelines on physical activity, sedentary behaviour, and sleep (2019), and the WHO standards for improving ECD (2021), the ECECS can provide structured, supportive environments that foster active play, adequate sleep, and reduced sedentary time. These settings could facilitate healthy physical growth and contribute to children's cognitive, emotional, and social development in the critical years before formal schooling begins.

Recent global data highlight the pressing need for early interventions to address the rising burden of childhood obesity. According to the Global Burden of Disease Study (GBD 2021), the combined prevalence of overweight and obesity among children and adolescents more than doubled between 1990 and 2021, with the prevalence of obesity alone tripling during this

period (GBD 2021 Adolescent BMI Collaborators, 2025). In addition, the WHO (2025) reported that approximately 35 million children under the age of five were affected by overweight or obesity in 2024. These concerning trends are increasingly evident in LMICs, where the prevalence of childhood obesity has escalated rapidly in recent years (Lobstein & Brinsden, 2019).

These patterns reinforce the need for early life surveillance of movement behaviours, particularly in under researched regions such as SSA. Guided by the BEF (Sallis et al., 2000), which advocates a stepwise approach from identifying behavioural risk factors to informing policy and practice (Carson et al., 2024), the current thesis focuses on surveillance and promotion of movement behaviours among 3 to 4 year old children in Tanzania. The thesis contributes new evidence to support early interventions that may help mitigate the rising incidence of childhood obesity in LMICs.

5.5 Policy implications and recommendations for practice

The findings of the current thesis have implications for the promotion of early childhood health, educational policy, and public health strategy in Tanzania and across SSA. As countries in the region continue to experience rapid socio-cultural and economic transitions, including increasing urbanisation and shifts in family structures, such as the rise in single-parent households, there is growing recognition of the need to integrate 24-hour movement behaviours into national policy frameworks (United Nations, Department of Economic and Social Affairs, Division for Inclusive Social Development [UNDESA DISD], 2022). The increase in single-parent households may have important implications for children's 24-hour movement behaviours. Evidence for these associations is largely derived from studies conducted in HICs, where single parents often balance employment, childcare, and household responsibilities independently, which may limit opportunities to supervise outdoor play or facilitate participation in organised physical activity (Salmon et al., 2011). Consequently, children aged 2–18 years may engage more frequently in screen-based or other sedentary behaviours (Salmon et al., 2011). Additionally, financial constraints, which are more prevalent in single-parent households, may restrict access to safe play environments and recreational opportunities (Thomson et al., 2012; Tillman et al., 2007). However, the extent to which these findings can be generalised to other settings, particularly the LMICs, remains uncertain due to differences in social structures, built environments, and cultural practices.

Although many single parents provide structured and supportive home environments, broader shifts in family structure may influence 24-hour movement behaviour patterns at the population level and should be considered in the development of policies and interventions (Langøy et al., 2019).

However, it is essential to acknowledge that the findings presented in the current thesis are preliminary and, therefore, do not justify immediate policy reform. Rather, they provide a foundational evidence base to guide future research. If expanded and validated through large scale investigations such as the forthcoming SUNRISE main study, this evidence could meaningfully inform the development of national policies and contextually appropriate interventions. The key implications for the current thesis are outlined below.

5.5.1 Establishing the foundations: Measurement and surveillance

The current thesis makes a substantial contribution by demonstrating the feasibility of assessing 24-hour movement behaviours in Tanzanian children aged 3 to 4 years, a demographic for which data were previously lacking. The study provides evidence of the feasibility of a measurement method based on the SUNRISE protocol, including ActiGraph accelerometers and structured SUNRISE questionnaires. The methods used in the Tanzania pilot study could inform national surveillance systems and population-based surveys to monitor trends in compliance with global guidelines, which are currently lacking in Tanzania and many other low-income countries globally (Okely et al., 2021). The use of these measurement methods is helpful for large scale surveillance studies (potentially modified to make them more practical e.g. step counting rather than accelerometry for measurement of TPA as suggested by Mwase-Vuma et al., 2022) because they generate data that can be used to compare countries and groups of countries, and to ensure a national surveillance system for young children is consistent and sustained to inform policies and interventions that aim to promote physical activity and reduce sedentary lifestyles (WHO 2022). The thesis established a practical and culturally relevant basis for national surveillance of the movement behaviours in Tanzania. Findings from the Tanzanian SUNRISE pilot study indicated that the SUNRISE protocol could serve as a scalable approach for assessing physical activity, sedentary behaviour, and sleep during early childhood, a crucial developmental phase often neglected in public health surveillance.

Incorporating these methods into extensive health and education monitoring systems could strengthen national efforts to monitor compliance with WHO guidelines and facilitate more detailed analyses of population trends over time.

5.5.2 Baseline data to support future surveillance

The current thesis presents preliminary data on young children's compliance with the global 24-hour movement guidelines, serving as a foundational reference for future surveillance and monitoring initiatives. These baseline findings should enable future comparisons with other studies conducted in similar contexts within SSA and globally, thereby contributing to a broader understanding of movement behaviours in early childhood. Rather than serving as a definitive guide, the current thesis should be regarded as an important initial step in understanding levels of compliance with the movement behaviour guidelines and the correlates of compliance. The SUNRISE main study may have the potential to provide more robust and generalisable data across Tanzania. To progress through the stages of the BEF, which is a commonly utilised model for guiding research on health-related behaviours, future SUNRISE main study data will be important.

5.5.3 Urban and rural similarities in young children's movement behaviours

Study 3 of the current thesis examined compliance with the WHO's global 24-hour movement guidelines among young children across LMICs, with a specific focus on urban rural differences. The findings revealed no statistically significant differences between rural and urban children in meeting the individual or combined movement behaviour guidelines. This result highlights an important preliminary observation: insufficient compliance with movement behaviour guidelines appears to be widespread among young children in both urban and rural contexts in LMICs.

Understanding the distribution of these behaviours between urban and rural areas is important for the development of equitable public health strategies. The research from this thesis indicates that a small proportion of children, regardless of their place of residence, complied with the WHO guidelines for physical activity, sedentary behaviour, and sleep.

If this trend is confirmed by larger, more representative samples, such as the SUNRISE main studies, it suggests that the challenge of promoting healthy movement behaviours in young children is not limited to urban settings but is relevant in rural areas. Therefore, if future studies confirm the results of the present thesis, it is imperative that both urban and rural communities receive equal attention in monitoring efforts and the formulation of interventions.

Investing in low cost, contextually appropriate, and scalable interventions has the potential to reduce the growing burden of childhood obesity, improve developmental outcomes, and ensure that all children, regardless of geographic location, sex, or socioeconomic status are given the opportunity to thrive. The findings presented in this thesis highlight the limited awareness and low compliance with movement behaviour guidelines among preschoolers in Tanzania, emphasising the need for broader dissemination of the WHO's global 24-hour movement guidelines. Global efforts like SUNRISE, could play a role in informing policy makers about the importance of young children's movement behaviours, with the hope of leading these authorities to prioritise them.

5.6 Proposed next step for this project

Building on the progress of this PhD research, the next key step may be to develop and submit a detailed funding proposal to support the implementation of the SUNRISE main study in Tanzania. As noted above, this large scale, nationally representative study aims to recruit approximately 1,000 children aged 3 to 4 years from diverse geographic, socioeconomic, and cultural contexts. Its primary objective is to generate high-quality, context specific data on physical activity, sedentary behaviour, and sleep.

The SUNRISE main study will provide a more robust empirical basis to inform targeted public health interventions, aid in the development of national and sub national policies, and encourage early prevention strategies for non-communicable diseases, such as childhood obesity. By aligning the study with the BEF, the research will also enable a systematic transition from behavioural monitoring to the design of interventions and policy translation.

5.7 Other research opportunities

Although Tanzania has made commendable progress in formalising and expanding access to pre primary education significant disparities remain, particularly among young children residing in rural and socioeconomically disadvantaged communities. Children under the age of five are not eligible to enrol in formal government schools, and therefore often rely on private or faith-based nursery schools, which typically require parental financial contributions. This reliance creates an additional barrier for families with limited economic resources (Shukia & Marobo, 2022).

The current research focused exclusively on children aged 3 to 4 years who were enrolled in ECEC centres. While this approach aligns with international protocols for SUNRISE, it is important to recognise that the movement behaviours of children attending ECEC programmes may differ significantly from those of their non-enrolled peers. This distinction is particularly relevant in the Tanzanian context, where early childhood education remains non-compulsory, and participation is far from universal. As of recent estimates, only approximately 46% of eligible children in this age group are enrolled in formal ECEC settings, despite the existence of a national ECD strategy aimed at improving enrolment and access (MoEST, 2023). Therefore, future studies should consider including children outside of ECEC settings to ensure more representative and comprehensive data that reflect the wider population of Tanzanian children.

There exists a notable dearth in longitudinal research originating from SSA that investigates the relationship between early childhood movement behaviours and subsequent health and developmental outcomes. In contrast, the majority of existing evidence is derived from high-income countries, where studies such as those conducted by McNeill et al. (2020) and Kracht et al. (2020) have demonstrated that early compliance with the movement behaviour guidelines is predictive of favourable health outcomes, including enhanced motor development and healthier weight trajectories. Undertaking similar longitudinal studies in SSA would not only broaden the global evidence base but also yield region specific insights to strengthen the national initiatives in Tanzania aimed at preventing NCDs and promoting early childhood development through healthier daily routines.

5.8 The overall strengths and limitations of the thesis

Specific strengths and limitations of each study within this thesis have been addressed in detail in their respective chapters (i.e., Chapters 2, 3, and 4). This section focuses on discussing the key strengths and limitations of the overall thesis. Firstly, the current thesis makes a novel contribution by presenting the first pilot study to assess compliance with the global 24-hour movement behaviour guidelines in Tanzania. It is also among the few studies to specifically focus on 3 to 4 year old children within a SSA context. Further, the research contributes to the limited pool of studies incorporating data from a globally diverse sample of young children, particularly from LMICs, which remain significantly underrepresented in the current literature. Again, the methodologies employed across the three studies were rigorous and consistent with established best practices, offering valuable insights for both researchers and practitioners and providing a strong foundation for future replication and scale up.

Another key strength of this thesis is its adoption of the internationally recognised SUNRISE study protocol, which enabled the standardisation of data collection procedures. Furthermore, the translation and cultural adaptation of study tools such as the study questionnaires into Swahili, as detailed in 3, enhanced the accessibility and comprehension of the tools at the community level, thereby improving data quality and participant engagement (Okely et al., 2021).

Additionally, three staff members from the TFNC, together with the PhD candidate, participated in intensive training on data collection methods. This strengthened institutional capacity and fostered local ownership of future research on movement behaviours. However, this thesis is not without limitations. Primarily, it is important to recognise that the studies presented are preliminary and situated at the initial stages of the BEF. Consequently, while they are important in establishing foundational knowledge, they are not yet adequate to directly inform or influence policy and practice. This limitation is intrinsic to early phase research and reflects the gradual and cumulative nature of evidence building necessary for policy translation.

Several methodological challenges were encountered by some of the included studies and warrant a brief discussion. One key limitation was the reliance on parent proxy report measures to assess certain components of 24-hour movement behaviours.

Although such methods are practical and often necessary in large scale research involving young children, parent reported data are subject to recall bias, social desirability bias, and limited observational accuracy factors that may compromise the validity of the findings (Hinkley et al 2012). In the current thesis, sedentary screen time, restrained sitting, and sleep duration were all assessed through parent reported questionnaires. Among these, sleep duration was likely to be estimated with a moderate degree of accuracy, as parents typically oversee bedtime routines and sleep wake cycles but cannot confirm the nap times at nursery (Galland et al., 2012). This finding is further supported by the validation work of Zhang et al. (2025), who examined the SUNRISE parent report questionnaire for sleep and found evidence of reasonable validity for estimating preschoolers' overnight sleep duration. Their study reported moderate to strong correlations between questionnaire-derived and accelerometer derived estimates, with only small average error, indicating that the tool yields reliable group level data. These results suggest that the SUNRISE parent report questionnaire demonstrates acceptable reliability and validity for assessing sleep duration, timing, and related family practices among preschool aged children, particularly in resource constrained settings. However, confidence is lower for estimates of sedentary screen time and restrained sitting, given that these behaviours may occur across multiple settings and times of day, not all of which are directly observed by caregivers (Lubans et al., 2011; Vanderlo et al., 2015). This variation in measurement precision across behavioural components represents a significant limitation. Future studies should prioritise the use of validated objective tools where feasible or incorporate methods to triangulate parent reported data to enhance measurement validity. The narrow focus on 3 to 4 year old children, while aligned with the SUNRISE protocol, also constrains the applicability of findings across the wider early childhood spectrum, particularly among infants and older preschool aged children. Differences in developmental stages may influence movement behaviours and their correlates, which this thesis does not fully capture. Study 2 (chapter 3) of this thesis, which was the SUNRISE Tanzania pilot study, used the device-based measurements specifically ActiGraph accelerometers. These devices were unfamiliar to many parents and, in some instances, elicited concerns or misconceptions such as associations with witchcraft that affected participation and consent. This might have resulted in reduced compliance with the accelerometry protocol.

5.9 Conclusions

Collectively, these studies underscore that, despite the promising progress achieved through the SUNRISE project, there remains a critical need for comprehensive and representative surveillance of early childhood movement behaviours in Tanzania and other LMICs. By systematically progressing from a regional evidence review to a national pilot study and subsequently to a broader comparison among LMICs, this thesis offers valuable initial steps toward addressing a significant knowledge gap concerning children aged 3 to 4 years. It also supports future research and initiatives aimed at promoting healthy behaviours in young children.

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APPENDICES

Appendix A: SUNRISE Parent/Caregiver Questionnaire



Parent questionnaire interview in Indonesia

Office use only

Child ID: _____

INTERNATIONAL STUDY OF 24-HOUR MOVEMENT BEHAVIOURS IN THE EARLY YEARS

PARENT/CAREGIVER QUESTIONNAIRE

This questionnaire is to be administered/completed by the MAIN caregiver of the child who lives with them and is 3 or 4 years old at the time of interview. A separate questionnaire should be used for each eligible child.

MODULE OF CHILD AND CAREGIVER BACKGROUND			
1.	What is the date of birth of the child? (dd/mm/yyyy)	2.	If the child's date of birth is not known, how old is the child in years? (Age in completed year)
	____/____/____		
3.	Parent/caregiver's relationship to the child participating in the study?		
	☐ Mother ☐ Father ☐ Grandmother ☐ Grandfather ☐ Legal Guardian ☐ Other (please specify):		
4.	What is the sex of the child?	5.	What is the gender of the main caregiver?
	☐ Boy ☐ Girl		☐ Male ☐ Female ☐ Other ☐ Non specific
6.	What is your (parent/caregiver) date of birth? (dd/mm/yyyy)	7.	If you (parent/caregiver) do not know your date of birth, how old are you (in years)?
	____/____/____		
8.	What is the highest level of parental/caregiver education completed by a member of your household?		
	☐ No formal schooling ☐ Primary school ☐ Secondary or high school ☐ Vocational education ☐ Tertiary education ☐ Don't know/refused		
9.	What is your ethnic group/racial group/cultural subgroup/cultural background? Multiple answers possible.		
	☐ Asian ☐ Aboriginal/Torres Strait Islander ☐ Middle Eastern ☐ European ☐ African		

	☐ Other (please specify):
--	--

CORE: SEDENTARY BEHAVIOUR, SCREEN TIME 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 the past week, were there any days where the 3 to 4 year old child who is participating in this study was restrained for more than one hour at a time in a stroller, car seat, or on back or a scooter/motorbike?	
	☐ Yes ☐ No	
11.	Over a typical weekday , how much time does the child spend as a passenger in a motor vehicle (e.g. a car, bus, motorcycle)	hrsmins
12.	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)	 hrsmins
13.	On a typical weekday , how much time does your child spend outside?	 hrs mins
14.	On a typical weekend day , how much time does your child spend outside?	 hrs mins
15a.	In the past three days, has the child: Gone outside the home to play (alone/with an adult/older child)?	
	☐ Yes ☐ No	
5b.	If yes, where did the child go? (tick as many as appropriate) ☐ On the property (i.e. Garden/yard) ☐ To a friend/relative's home ☐ To a park/square or playground ☐ To a swimming pool/creek/river/dam/waterhole/beach ☐ To the street ☐ To the bush/forest/nature environment ☐ Any other not mentioned? (please specify)	

15c.	In the past three days, has the child: Not gone/been allowed to go/been taken outside to play because of (tick as many as appropriate)	
	☐ Heat ☐ Cold ☐ Rain ☐ Air pollution (dirty, smoky, smelly) ☐ Water pollution ☐ Any other not mentioned? (please specify) ☐ Not relevant ☐ Noise or crowding ☐ Garbage/rubbish ☐ Social unrest ☐ Dangers such as crime/kidnapping ☐ Dangers such as traffic	
16.	On a 24-hour period in the past week , how much time did the 3 to 4year old child who is participating in this study spend 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? Please record this as accurately as you can to the nearest minute	 hrs mins
17.	How often do you use an electronic screen 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 screen 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 travel time 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 while going for walks 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 during bedtime routine with the child?					
	☐ Never ☐ Less than once a week ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know					
25a.	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? If no, go to question 26					
	☐ Yes ☐ No ☐ Don't know					
25b.	If yes, how close to bedtime does the child usually use these devices?					
	☐ Closer than 30 minutes before bedtime ☐ 30 mins to less than 1 hour before bedtime ☐ Between 1 and 2 hours before bedtime					
26.	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					
27.	How many hours of sleep does this child get in a typical 24hours day (<u>including</u> naps)?		 hrsmins			
28a.	Does your child nap? If yes, go to 28b		28b.	If yes, what time does your child nap?		
	☐ Yes ☐ No		Begin time: End time:			
29a.	Does the child have a consistent bedtime?		29b.	Does this child have a consistent wakeup 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
30a.	What time does your child go to bed at night?	30b.	What time does your child get up in the morning?
	Bed time: PM		Wake-up time: AM
31.	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, throw off bedclothes) while 7 would indicate settles and drifts off to sleep with a few minutes, sleeps right through the night, and has a very sound, deep sleep)		
	☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ Don't know		
32a.	In the past three days, has the child: Not got enough sleep?		
	☐ Yes ☐ No		
32b.	If Yes, was it because of: (tick as many as appropriate)		
	☐ Outside noise (like traffic/train/street noises) ☐ Indoor noise ☐ Too Hot ☐ Too cold ☐ Too much light coming into the room ☐ Other (please specify)		
33a	Does the child sleep in their own bedroom by themselves?		
	☐ Yes ☐ No		
33b.	If No, how many other people sleep in the same room as the child?		
	Children Adults (18 years and older)		
33c.	If No, how many other people sleep in the same bed as the child?		
	Not Relevant Children Adults (18 years and older)		
34.	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						
FOOD SOURCES							
35 a.	Do you ever give your child money to buy food?						
	☐ Yes ☐ No						
35 b.	If Yes , on how many days per week? _____ days						
36 a.	Does your child take any food to the childcare centre?						
	☐ Yes ☐ No						
36 b.	If Yes , which meal(s) do they typically take with them and on how many days per week?						
		Once a week	Twice a week	3 times a week	4 times a week	5 or more times a week	No
	Breakfast	☐	☐	☐	☐	☐	☐
	Lunch	☐	☐	☐	☐	☐	☐
	Dinner	☐	☐	☐	☐	☐	☐
	Snacks	☐	☐	☐	☐	☐	☐
37.	Does your child have any special dietary requirements/restrictions (e.g. dairy-free food, gluten-free food)?						
	☐ Yes ☐ No						
37 a.	If Yes , please specify _____						
DIETARY DIVERSITY¹							
38.	Did your child eat any of the following types of food yesterday, during the day or night?						
		Yes	No	Don't know			
	Grains, roots and tubers (e.g. Bread, cereals, noodles, pasta, potatoes, rice)	☐	☐	☐			

	Legumes and nuts (e.g. Beans, peas, lentils, walnuts, or seeds)	☐	☐	☐
	Dairy/milk products (e.g. Cheese, curd, custard, ice-cream, kefir, milk and yogurt. Exception of	☐	☐	☐
	butter and sour cream)			
	Fresh foods (e.g. meat, fish, poultry and liver/organ meats)	☐	☐	☐
	Eggs	☐	☐	☐
	Vitamin A rich fruits and vegetables (e.g. green leafy vegetables, yellow and orange inside vegetables and orange non-citrus fruits)	☐	☐	☐
	Other fruits and vegetables (e.g. Apple, banana, orange, pear)	☐	☐	☐

EATING BEHAVIOURS AT HOME

39.	How often is the TV or an electronic screen device on during meal or snack time?
	☐ Never ☐ Rarely ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know
40.	How often do you sit with your child during meals?
	☐ Never ☐ Rarely ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know
41.	How often do all of the family sit together during a main meal?
	☐ Never ☐ Rarely ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know
42.	How often does your child eat or drink different foods and beverages to you during meal and snack times?
	☐ Never ☐ Rarely ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know
43.	How often does your child have snacks like chips, biscuits, cakes, candies, chocolate, pastries, and sweets between meals?
	☐ Never ☐ Rarely ☐ Once a week ☐ Most days ☐ Every day ☐ Don't know
44.	How often does your child drink sugary drinks (e.g. Cordials, flavoured milk, fruit juice, soda, soft drink)?

Appendix B: Centre Information Questionnaire



Centre Information Questionnaire

1	Centre Name:	1a.	Centre number:
.			
			

2 .	Data collection start date:	3.	Data collection end date:
	____ / ____ / ____		____ / ____ / ____
4 .	Sector:		
	☐ Urban ☐ Rural		
5 .	Total number of eligible children at the centre:		
			
6 .	Number of eligible children at the centre that did consent to participate in the study		
			
7 .	Did any children at this centre withdraw from the study after consenting?		
	☐ Yes ☐ No		
7 a.	How many children withdrew from this centre after consenting?	7b.	Why did they withdraw?
			
8 .	Do the eligible children who are participating in the SUNRISE Study have a naptime in this centre?		
	☐ Yes ☐ No		
8 a.	What time does the nap start? (24hr time in hours and minutes)	8b.	What time does the nap end? (24hr time in hours and minutes)
			
9.	In which season are you collecting data in this centre?		
	☐ Spring ☐ Summer ☐ Autumn ☐ Winter		

	☐ Other (please specify).....		
10.	Were there any ActiGraphs lost in this centre? If no, please go to question 11	10a.	How many monitors were lost in this centre?
	☐ Yes ☐ No		
10b.	What are the serial numbers of the lost UOW ActiGraphs in this centre?		
			
11.	In the past three days, have the eligible children who are participating in the SUNRISE Study:		
11a.	Not gone/been allowed to go/been taken outside to play at the because of (tick as many as appropriate)	11b.	Not got enough sleep during nap time because of (tick as many as appropriate)
	☐ Heat ☐ Cold ☐ Rain ☐ Air pollution (dirty, smoky, smelly) ☐ Noise ☐ Other, please specify:		☐ Indoor noise ☐ Outdoor noise (traffic/train/street noises) ☐ Too hot ☐ Too cold ☐ Too much light coming in to the room ☐ Other, please specify:
12.	Does the childcare centre provide any meals or snacks? (Please tick all that applies)		
	☐ Breakfast ☐ Lunch ☐ Dinner ☐ Snacks		

	☐ None
13.	Does the childcare centre provide a cooked meal every day?
	☐ Yes ☐ No
14.	Does the childcare centre have any rules about what food they can bring?
	☐ Yes ☐ No
14a.	If Yes , what are the rules?
	☐ Not permitted to bring food to the childcare centre ☐ Other rules (please specify): _____
15.	Any other relevant information/comments about this centre or any problems during data collection in this centre?
	

Please make a screenshot each day at the main outdoor playtime or at 12PM if there is not a scheduled playtime using the Plume app and upload them into REDCap

Appendix C: Feasibility assessment Questionnaire



UNIVERSITY
OF WOLLONGONG
AUSTRALIA

Country: _____ **Childcare centre:** _____ **Date of focus group:** ____/____/____

Thank you for taking part in the SUNRISE pilot study. We greatly appreciate all your help and support.

1. How did you find the parent/caregiver questionnaire? Were there any questions that you didn't understand or find hard to answer? (please have hard copies of the questionnaire for parents/caregivers to access)

2. Did the children enjoy participating in the study? Was there anything you think they did not enjoy or that could be improved?

3. How did you find your child went wearing the accelerometer for five days? Were there any problems? If so, can you tell us about them and offer any advice on how we could improve this?

4. Do you have any other comments to make?

Thank you again for your time and feedback.

Appendix D: Focus Group/ Interview Template Staff

Do the children in your centre meet the Movement Guidelines?

International Study of Movement Behaviours in the Early Years

A study conducted by researchers from Tanzania Food and Nutrition Centre



The Researchers who you can contact anytime with questions:

Dr Leyna German Phone no: +255782847320 Email: gerryleyna@yahoo.com,

Jackline Nusurupia Phone no: +255767241825 Email: jacklinejema10@gmail.com

Why this information sheet?

We would like to invite children at your Centre to participate in the SUNRISE pilot study. This International Study of Movement Behaviours in the Early Years is being conducted in multiple countries. In **Tanzania** this study is being piloted by researchers from **Tanzania Food and Nutrition Center** in collaboration with the University of Wollongong, Australia.



Background of the research

Consider a young child's physical and motor development in the context of how they move throughout a typical day. It is usually a combination of sleep, sitting, standing, and different intensities of physical activity, the latter mostly in the form of play and other activities of daily living. We know little about how these behaviours – individually and in combination – influence one another and how they relate to healthy growth and development.

Benefits and funding of the research

The primary aim of the SUNRISE Study is to determine the proportion of 3- and 4-year old children who meet the **World Health Organization** (WHO) Global 24-hour Movement Guidelines for the Early Years in participating countries. This research will also:

1. Determine if the proportions of children meeting the guidelines differ by sex, household education levels, urban/rural setting, or country income levels.
2. Investigate if meeting the WHO guidelines and movement behaviours is associated with health and developmental outcomes; and
3. Identify potential factors associated with the movement behaviours and meeting the guidelines.

The purpose of the Pilot Study is to determine the feasibility and acceptability of the data collection measures proposed for the Main Study, and whether their use is appropriate across cultures. Approximately 100 children per country, and their primary caregiver, will participate in the Pilot Study. The results of this study may be reported at conferences, published in academic journals, and used to apply for future funding. In all cases data will only be reported in anonymised aggregate form. The findings from the study will contribute to the global evidence on movement behaviours for preschoolers.

The coordination of this study has been funded in Australia by an NHMRC Investigator Grant and University of Strathclyde and Tanzania Food and Nutrition Centre.

What does participation involve?

You will be asked to distribute an information sheet/consent form to parents/primary caregiver. Data collectors will visit your centre at an agreed time and consenting children will be asked individually to do various activities with a data collector (jumping, balancing, running). The data collectors will also measure the child's height, weight and grip strength and play some iPad games.



The iPad games are enjoyable for children and allow us to assess some of their cognitive abilities such as their working memory. In total, these assessments take 20-25 minutes to complete per child.



Each participating child will be asked to wear two lightweight activity monitors for 5 days to measure their physical activity: 1) a small monitor on a strap to wear around their non-dominant wrist (like a watch), including in water and when they are sleeping; and 2) a monitor on a belt, which needs to be worn all day except for during water-based activities. The activity monitors do not record the location of the child. Consenting parents will be asked to complete a brief questionnaire that includes questions related to their child's demographic information, sedentary time, screen time, sleep and nutrition. This should take parents 15-20 minutes to complete.

Finally, at the conclusion of the data collection occurring within your centre, you, the director, will be asked to complete a brief questionnaire (5-10 minutes). This questionnaire will focus on environmental factors in the centre that may be associated with the children's movement behaviours. This includes questions about the participating children's nap routines, nutrition, sedentary behaviour, physical activity at the centre and any restrictions placed on the centre due to the COVID-19 pandemic. You have the option to refuse to answer any questions. Accordingly, approval is sought for your participation in the centre questionnaire and to visit your centre for a number of days to complete the child assessments at days and times that you deem would be minimally disruptive to your centre's operations (the exact number of days will depend upon the number of children participating in the study).

Low risks in participation

Apart from the time taken to participate in this study, **we foresee no risks** to participation in this research. Children's participation in this study is voluntary, parents may decline to participate. Note that all data collected will be transferred and stored securely at the University of Wollongong and kept strictly confidential. Your centre and the children/parents will not be identified in any part of the research

Research findings and future use of the information collected

The aggregated results for your centre will be reported back at a parent information session. You will not receive individual child results. The deidentified data collected from the children within your centre will be aggregated by country and compared with other participating countries regarding the proportion of children meeting 24-hour movement guidelines (e.g., % of children in your country who meet the guidelines, vs. % of children in another country who meet the guidelines). The de-identified data will be stored in a password-protected database with access managed by the SUNRISE Coordinating Centre Data Management team.

The collected information will primarily be used by the Chief Investigator/s in each country and the SUNRISE Coordinating Centre Data Management team for the study aims described above. However, it may be of interest to investigate new research questions in the future, possibly with other researchers. De-identified data might therefore be shared with others for the purpose of research. Future use of the data will be subject to approval by UOW Ethics, and the Ethics committees of the countries involved in the study. Information about new use of data will be available at <https://sunrise-study.com/>. Deidentified data may also be published in an open database/repository when required by publishers. Any personal identifying information will be removed from the data, and it will not be able to identify you or the participating children/parents or your centre.

Next steps to participation

If you have further questions, please sign and return the consent form to the researchers involved in this study. As mentioned previously, you will receive a centre information questionnaire when the data collectors visit your centre. If you have any further questions, please feel free to contact:

Dr Leyna German Phone no: +255782847320 Email: gerryleyna@yahoo.com,
Jackline Nusurupia Phone no: +255767241825 Email: jacklinejema10@gmail.com

Ethics review and complaints

This study has been reviewed by the Human Research Ethics Committee (Social Science) of Tanzania National Institute for Medical Research (NIMR)

If you have any concerns or complaints regarding the way the research is or has been conducted, you can contact NIMRI through the following address:

3 Barrack Obama Road

P.O. Box 9653

Dar es Salaam

Tanzania

Should you require any further information please do not hesitate to contact members of the research team.

You can find more information about the **SUNRISE Study** at <https://sunrise-study.com/>

Participant Consent Form

I _____ agree for me and my and Centre take part in the pilot study entitled: "International Study of Movement Behaviour in the Early Years" and for children (who have provided verbal assent; and whose parents have provided written consent) at my centre to participate.

I understand that my centre's participation in this research will involve: (1) myself completing a 5-10-minute Centre Information Questionnaire; (2) permitting assessment of participating children aged 3 and 4-years-old within my centre, as described in the Centre Director

Information Sheet; and (3) distributing an information sheet/consent form to parents of the children within my centre.

I understand that the results of this study may be reported at conferences and published in academic journals. In all cases data will only be reported in anonymised aggregate form, and I consent for it to be used in this manner.

I consent to the de-identified data relating to my centre being used in future research that has been approved by the Tanzania National Institute for Medical Research (NIMR). I have read the information in this form and had a chance to ask questions.

(Please circle

YES

NO

If you consent for this research to occur in your centre, please sign and complete this consent form and return it to the researchers involved in this study.

(Centre Director signature)

Date:

Appendix E: SUNRISE international study protocol

Accelerometry

6. Measurements of 24-hour Movement behaviours

Accelerometry will be used to objectively assess the child's 24-hour movement behaviours (physical activity, sedentary behaviour and sleep). Two accelerometers will be used in this phase of the SUNRISE pilot study: ActiGraph GT3X+/GT3X-BT and Axivity AX3.

Accelerometer	Description
	The Actigraph GT3X+/GT3X-BT is a small, lightweight, triaxial device worn on an elasticized belt around the waist. The monitor captures physical activity, sedentary time and sleep by recording time-varying accelerations. These accelerations are digitized and expressed in the form of counts. Higher counts indicate higher levels of physical activity and lower counts indicate lower levels of physical activity.
	The Axivity AX3 is a triaxial accelerometer that is small (23 mm x 32.5 mm x 7.6 mm) and light weight (11 g). It can measure continuous time-series movement data at a wide range of sample rates (12.5 to 3200 Hertz) and durations (up to 30 days at 12.5Hertz). It is also waterproof and has a temperature sensor that allows for accurate wear time detection.

Accelerometer wearing protocol:

Each child is required to wear the ActiGraph and Axivity AX3 for 5 days. The ActiGraph needs to only be removed for water activities (such as bathing/showering, or swimming). The Axivity AX3 is waterproof and thus does not need to be removed for water activities. The monitors will be placed on the child on their first day of attendance during data collection. The monitors will be removed five days later, again during the time the child is attending pre-school/kindergarten.

Figure 1: Placement of the GT3X+ accelerometers on a preschool child.

Please note: the ACTi Graph can also be placed underneath the clothing.

6.1 ACTIGRAPH GT3X+ ACCELEROMETERS

6.1.1 Equipment checklist

- ActiGraph GT3X+ accelerometers
- Elasticized belts
- Serial number labels (e.g., 4 last digits of the monitor's serial number) – to be provided by each country and attached to the back of the monitors. This should also contain the local address of the research centre where the monitor would be returned if lost and found.
- Computer with ActiLife 6.12.1 software (lite version or full version) – to initialise and download monitors. **If you need a temporary license for the software, it is important that you let the SUNRISE UOW team know as soon as possible (sunrise-uowcentre@uow.edu.au).**
- Accelerometer to USB cables (Micro USB data cable)
- Multi-port USB hub (optional; provided by each country – see image on the right)



Figure 2: A GT3X+ accelerometer with an example of serial number label

6.1.2 Installing and activating ActiLife software

Please follow the steps outlined below to install and activate the ActiLife software:

- 1) Go to this link: <https://www.actigraphcorp.com/support/getactilifebykey/>
- 2) Enter the valid product key (*please let the SUNRISE UOW team know if you need a temporary licence*) and then click 'RETRIEVE'.

Enter your product key and click retrieve

If you do not have or have lost your product key, please contact our [customer support](#) team.

ex. ABCD-1234-EF-5678-90AB

RETRIEVE

I don't have my product key

- 3) Click 'Download'. Please make sure that you have downloaded the correct version of the software (i.e., v6.12.1 if you are using UOW's licence).

Your version of ActiLife

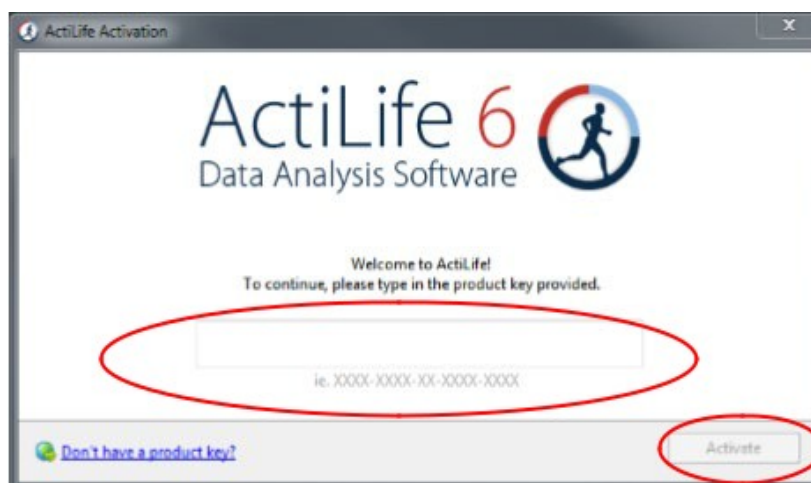
Product ActiLife	6.12.1
Released 11-16-2015	This release handles the new IMU data format in Link devices with firmware 1.4 and higher.
Version 6.12.1	IMPROVED
DOWNLOAD NOW	• Parse new IMU data format from Link devices. • When downloading data to network drives, ActiLife now has better checking for write permissions.
	FIXED
	• Make sure display values are reset on initialization. • Uploading multiple files to Data Vault crashed ActiLife for a few customers. This is now resolved.

- 4) Run the .exe file downloaded and follow the on-screen instructions to install the software.

5) Once the installation is completed, double click the ActiLife icon (see below image) on the desktop to open software.



6) You will be prompted to type in the product key (this is the same key that was used in Step 2 above) for activation during the first launch of the software. Click 'Activate'.



7) After activation, a screen (as shown below) will be displayed. This screen summarises the product type and the number of activations used and available, as well as the name and contact information of the person to whom the license is registered. Name, Email, and Organization fields must be populated in order to continue.



Please contact SUNRISE UOW team if you have any issues with the installation/activation of the software.

6.1.3 Charging the GT3X+ accelerometers

The GT3X+ accelerometers have a rechargeable battery that is capable of providing power for up to

21 days without recharging. The battery level can be viewed at any time by starting ActiLife and plugging in the device. The ActiLife 6 software will not allow initialization if the battery level is below 80%.

The GT3X+ accelerometers feature a small LED light that conveys messages depending on the flash sequence.

ActiGraph GT3X+ connected to the PC	
1 Flash	Battery is charging
2 Flashes	Battery is faulty
Steady On	Battery is charged

ActiGraph GT3X+ not connected to the PC

No flashes (LED off)

Actively collecting data or Battery is completely Dead

	Low battery – the monitor needs to be recharged
2 Flashes	
3 Flashes	Battery level has fallen below 3.1 volts and the unit has entered Halt Mode.
	OR the memory of the device is full

Recharging is accomplished by connecting the GT3X+ to any standard USB port. It takes approximately 4 hours to charge a fully depleted battery. Once the battery is completely charged (maximum voltage of approximately 4.18V), the LED light will remain illuminated (see image below). Multiple devices can be recharged at the same time using the USB hubs. When recharging multiple devices, ensure the USB hub is connected to the power point electricity and not the computer.

Data collectors need to ensure all GT3X+ accelerometers are fully charged before arriving at the childcare centre/pre-school/kindergarten/village and placing them on the children, particularly if there is a gap between initialising and fitting the accelerometers.



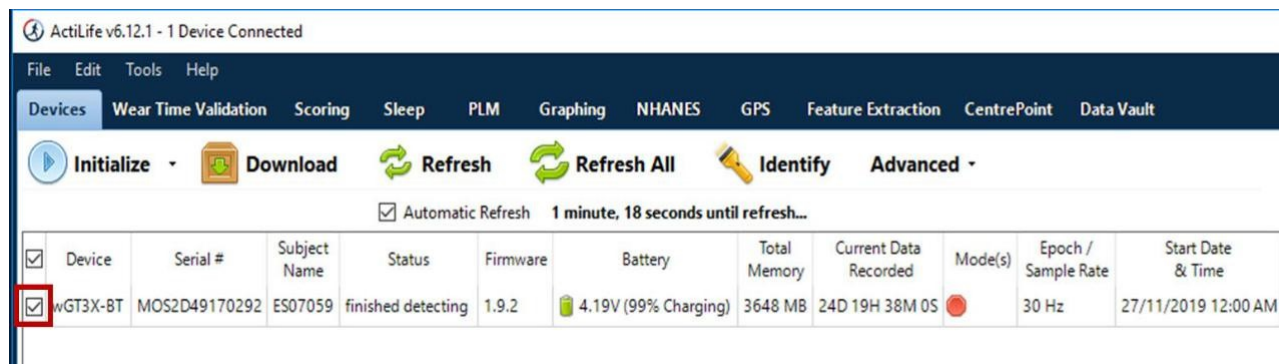
6.1.4 Initialising the GT3X+ accelerometers

The Chief Investigator from each country will explain who is responsible for initialising the monitors.

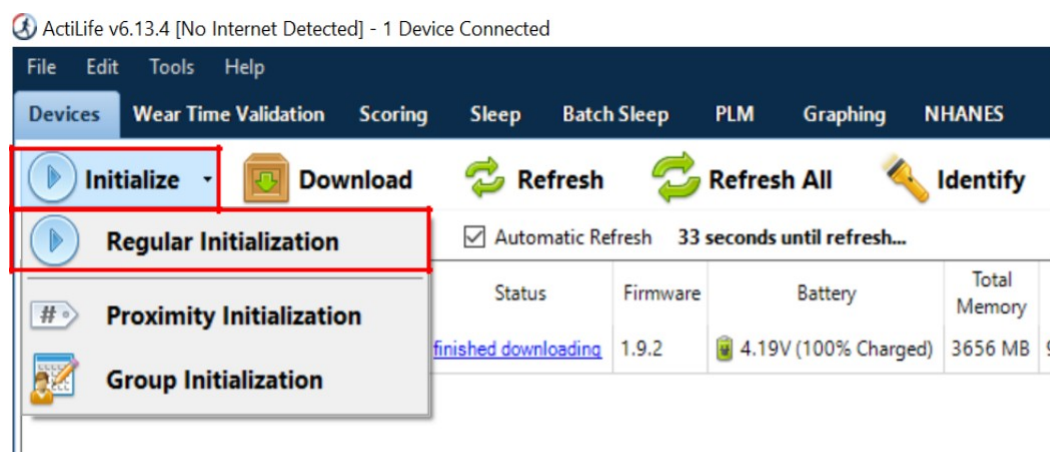
The ActiLife 6 software facilitates initialization and downloading of multiple accelerometers simultaneously.

To initialize the monitors:

- 1) Open ActiLife 6 software by clicking on the desktop icon.
- 2) Plug in the accelerometer(s) and wait for the accelerometer information to show up in the software. The accelerometer will be identified by the serial number.



- 3) Select the accelerometer(s) that will be initialized by checking the box beside the accelerometer(s) name.
- 4) Click on the "Initialize" button and then "Regular Initialization".



5) This will open the window as shown below.

Initialize Devices

Choose Initialization Parameters for 1 Device

Select Start Time: 23/07/2020 12:00 AM Default ☐ Use Stop Time? 6/08/2019 5:00 PM

Device Time: 22/07/2020 2:39:02 PM Use Local Computer Time ? Devices will continue collecting data until the battery dies.

wGT3X-BT (1)

Sample Rate: 30 Hz

LED Options

☐ Delay Mode LED ☐ Data Collection LED ☐ Wireless LED

Wireless Options

☐ Enable Wireless ☐ Heart Rate

Recording Options

Idle Sleep Mode: Disabled ?

6) Select start date for the day and time. For SUNRISE study, we want this to be **midnight at the start of the day** on which the monitor is to be placed on the child. So, if the monitor is to be placed on the child on the 23/07/2020 set this as the start date and the time as 12:00AM. This will allow faster data analysis by the coordinating centre resulting in data being available for each country sooner. It also standardizes the protocol across countries and allows the use of consistent macros for data reduction.

7) Make sure the "Use Stop Time?" is unchecked.

8) Device time – "Use Local Computer Time" after checking time is correct.

9) Under Epoch, select sample rate of 30 Hz Raw Data

10) Make sure the "Delay Mode LED" and "Data collection LED" are unchecked.

11) For Idle Sleep Mode select "Disable"

12) Then click the "Enter Subject Info" button. This will open the following window.

6.1.5 Fitting the GT3X+ accelerometers

Data collectors will be responsible for fitting the GT3X+ accelerometers to the children.

Before fitting the accelerometers on the children:

- Remember to fully charge the accelerometers the day before fitting.
- Determine the number of accelerometers that need to be prepared based on the number of anticipated consented children.
- Thread the accelerometers to elasticized belts.
- Have extra belts of different sizes for any changes required.
- Remember to regularly wash the belts between children.

When fitting the accelerometers to the children:

- 1) Discuss with the child what you are going to do in simple language they can understand. Offer the monitors to them. Let them touch and hold the monitors. This helps children become familiar with how the monitor feels and can ease any feeling of apprehension or hesitation.
- 2) Discuss with the child how the accelerometer needs to be worn in simple language that they can understand (call it a special belt, magic belt, superhero belt, activity monitor or an activity counter). Explain to the child that the monitor:
 - a) needs to be worn all day and all night
 - b) needs to be taken off when they go in water or have a bath/shower
 - c) can be worn underneath or over their clothes
 - d) needs to be worn by them and no-one else: "you cannot swap with a friend because that monitor is set specifically for you and if someone else wears it the computer in the monitor will think that they are you".

To fit the monitor, put the belt around the child's waist and fasten. Make sure the belt is snug against the child's body but not digging into the child's skin. **The monitor should be positioned over the right hip with the button facing upwards.**

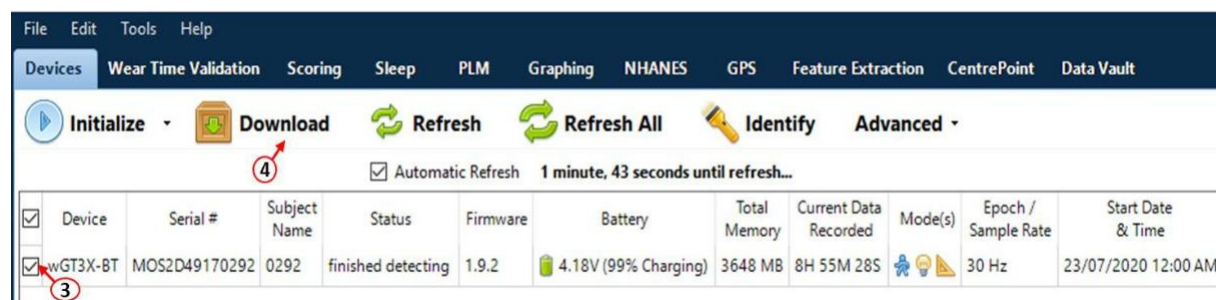


6.1.6 Downloading the GT3X+ data

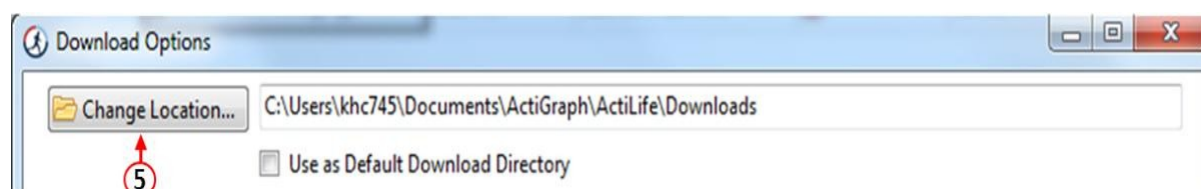
Each country will be responsible for downloading the data from the accelerometer after it has been worn. The instructions for downloading the data from the Actigraph is below.

- 1) Open the ActiLife 6 software by clicking on the desktop icon.

- 2) Plug in the accelerometer and wait for the accelerometer information to show up in the software. The accelerometer will be identified by the serial number.
- 3) Select the accelerometer that will be downloaded by checking the box beside the accelerometer name.
- 4) Click on the "Download" button. This will open a new window.

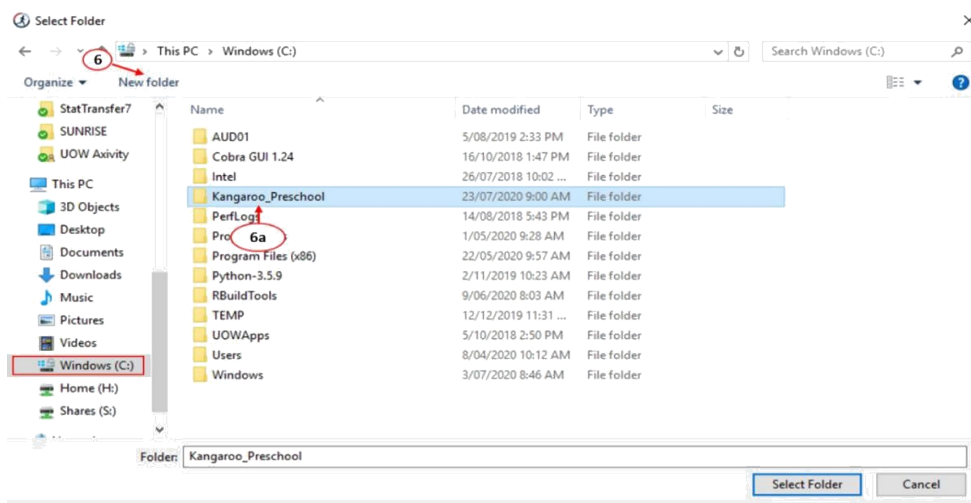


- 5) Click the "Change Location" button. During the first time doing this you will have to create a folder where you are going to save all the accelerometer files. For subsequent downloads skip to step 9.



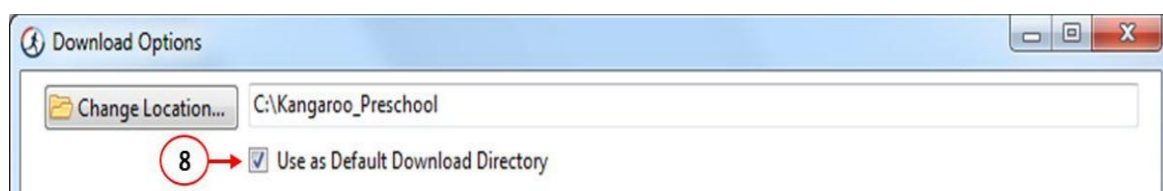
- 6) Select the Local Disk (C:) and click on the button "Make New Folder".

- a) Name the folder with the childcare centre name (e.g., "Kangaroo Preschool". Make a new folder for each childcare centre. This folder name will be de-identified with the preschool ID (Country letters (CA, CH, BR, PG, SA); Centre number (2 digits); For example, for Australia AU01) once all data has been collected.



7) Select the corresponding folder and click "OK". An example of the download location would be C:\Kangaroo_Preschool.

8) Click the box beside the "use as Default Download Directory", so every time a download happens the data will be saved to the same directory.



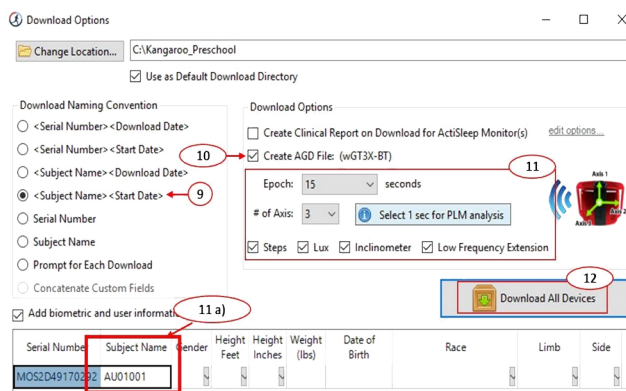
9) For "Data Naming Convention", select "<Subject Name> <Start Date>".

10) Select the box beside "Create AGD file".

11) Select: 15-second Epoch (15), 3 for the # of Axis, steps, lux, inclinometer, and low frequency extension.

a) **Change the subject name to the Child ID number entered in REDCap.** The child's ID number will consist of: Country letters (CA, CH, BR, PG, SA); Centre number (2 digits); Child number (3 digits). For example, for Australia AU01001. **If this is forgotten it will be hard to identify to the right person later on!**

12) Click "Download All Devices".



13) Once you have downloaded all children from this preschool, the "File Name" should be de-identified and include the child's ID only. The child's ID number will consist of: Country letters (CA, CH, BR, PG, SA); Centre number (2 digits); Child number (3 digits). For example, for Australia AU01001. **Please then ensure this number matches up with the one entered in REDCap.**

14) Select "Save".

15) The download is finished.

ActiLife v6.12.1 - 1 Device Connected

File	Edit	Tools	Help								
Devices	Wear Time Validation	Scoring	Sleep	PLM	Graphing	NHANES	GPS	Feature Extraction	CentrePoint	Data Vault	
Initialize	Download	Refresh	Refresh All	Identify	Advanced						
☒ Automatic Refresh 1 minute, 49 seconds until refresh...											
☒	Device	Serial #	Subject Name	Status	Firmware	Battery	Total Memory	Current Data Recorded	Mode(s)	Epoch / Sample Rate	Start Date & Time
☒	wGT3X-BT	MOS2D49170292	0292	finished downloading	1.9.2	4.19V (100% Charged)	3648 MB	9H 19M 18S		30 Hz	23/07/2020 12:00 AM

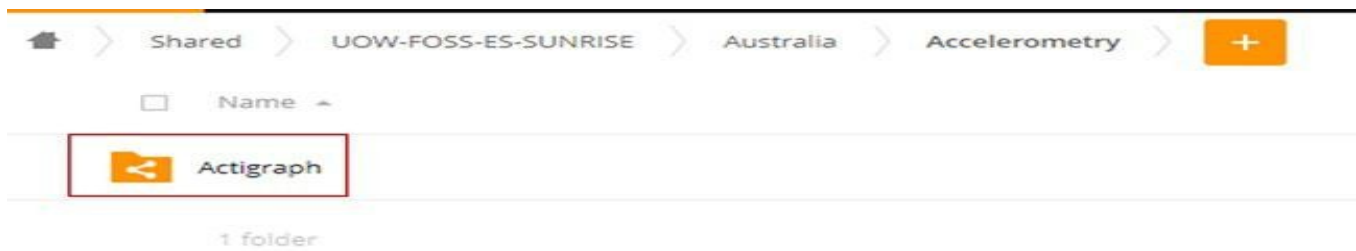
16) Check the monitor serial number, distribution and return dates against the information recorded in the REDCap to ensure the file naming is correct.

6.1.7 Uploading the GT3X+ data

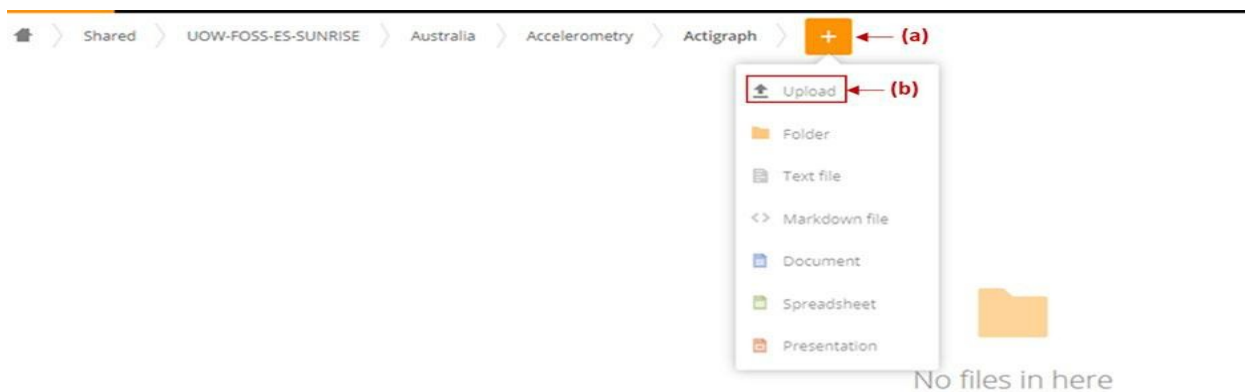
The instructions for uploading the Actigraph data to Cloudstor is below.

- 1) Log in to Cloudstor by using the link and password provided by the SUNRISE Coordinating Team (here use Australia's folder as an example).
- 2) Click on the 'Accelerometry' folder. Then click on the 'Actigraph' folder. This is where all the accelerometer data files should be uploaded to.

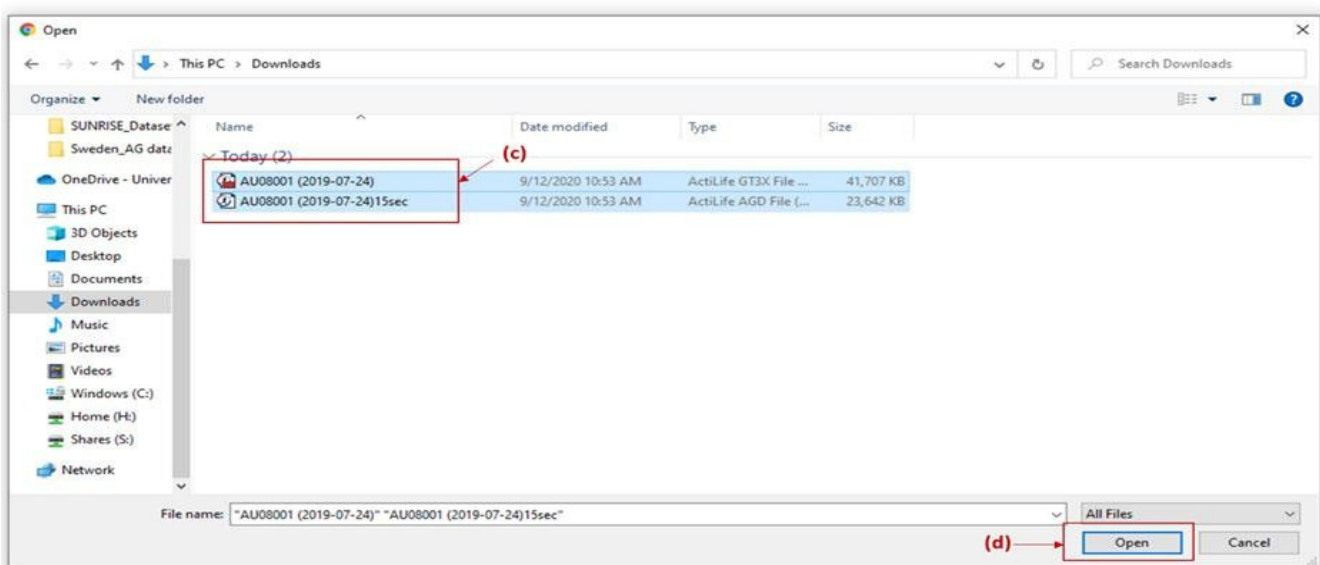




3) To upload the data files, click on the (a) "+" icon. Then select the (b) 'Upload' option. This will open a new window.



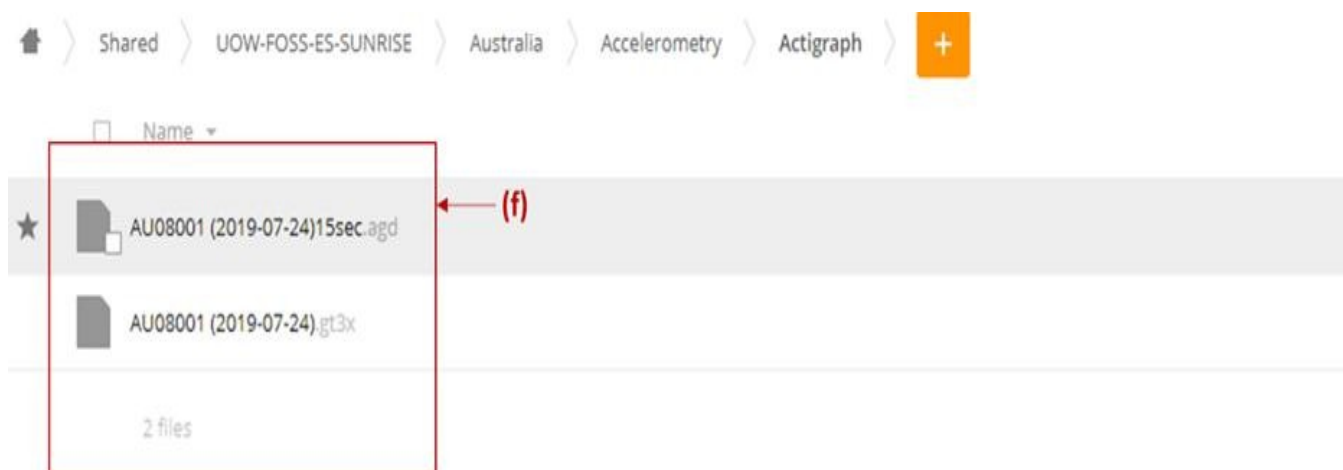
4) Go to the folder where you have saved the accelerometer data files. Select all the data files to be uploaded (c) and then click 'Open' (d).



5) The data files are now uploading. You can monitor the progress of the upload by looking at the status bar appeared next to the '+' icon (e). The bar will disappear once all the files have been uploaded.



6) Make sure that all the data files (two for each child ID – one with .agd extension and another one with .gt3x extension) have been uploaded on this page (f) before logging out.



6.3 REMOVING THE ACCELEROMETERS FROM CHILDREN

Removing both Actigraph GT3X and Axivity AX3 accelerometers from the children after it has been worn for 5 days:

1) Before the child leaves the childcare centre on the final day, remove the monitors from the child and record the date and time and who removed the monitors in REDCap.

If a child turns up to the centre without wearing a monitor:

- If you are at the childcare centre, please ask the child to wear for an additional day.



6.4 STRATEGIES TO INCREASE COMPLIANCE WITH MONITORS WEARING

During the 5 days, a number of strategies will need to be employed to ensure the children wear the monitors for at least three full days.

These include:

- Checking the children are wearing the monitors properly during your time in the centre.
- If the child is not wearing the monitors correctly (e.g., monitor is upside down, belt/wrist band is too loose or monitor is on the wrong side of the body), correct the monitor's position and explain how to wear the monitors again to the child in easy-to-understand language.
- Using the preferred method of contact, contact the parents with reminders about the monitors – e.g., send a reminder text message, call the parent, talk to the parent face-to-face when the child is being dropped off or picked up from childcare.
- Reading the child one or more of the stories (see previous page). The Chief Investigator has access to the English version of these in the SUNRISE folder on CloudStor.
- Some children respond if you explain the belt is secret and can be hidden away under clothes from the other children.

6.5 DATA MANAGEMENT

All accelerometer data should be uploaded to CloudStor after each data collection **session after de-identification**. The UOW Early Start Data Management Coordinator has sent each country's Chief Investigator an invitation to a shared folder in CloudStor to store the accelerometry data. When this hyperlink is opened you will be asked to enter the password sent in the email. This will then take you to a shared folder with your country's name. This folder is where you can upload accelerometer files for secure storage and subsequent analyses.

De-identification should be done as follows:

- 1) Child ID number will consist of: Country letters (CA, CH, BR, PG, SA); Centre number (2 digits); Child number (3 digits). For example, for Australia AU01001.
- 2) For a centre ID number Country letters (CA, CH, BR, PG, SA); Centre number (2 digits). For example, for Australia AU01.

Appendix F: Activity monitor instruction sheet



International Study
of 24-hour movement behaviours in the early years

Dear Parent/Caregiver,

Thank you for taking part in this important study. Here are a few points to remember over the **next 5 days**.

- Please wear this monitor every day, except when showering/taking a bath or swimming.

REMEMBER TO PUT IT BACK ON AS SOON AS POSSIBLE

- Please wear the monitor on your right hip, in a straight line down from the front of your armpit (see picture).
- Ensure that the black circle on the monitor is facing up
- The monitor can be worn on top or underneath clothes, whichever is most comfortable
- **PLEASE**, just do your usual activities.
- HAVE FUN!



Please return this monitor on.....

Thank you for your time and your cooperation!

For further information please contact (insert INVESTIGATOR NAME) and (PHONE), or email (EMAIL)

Appendix G: University of Wollongong ethics approval letter

Dear Professor, Okely,

I am pleased to advise that the application detailed below has been **approved. Please note, while approval has been granted through UOW ethics, please send through the ethics approvals from the specific sites as you gain them prior to commencing data collection.**

Ethics Number:	2018/044
Approval Date:	03/04/2018
Expiry Date:	02/04/2019
Project Title:	SUNRISE
Researchers:	Okely Tony; Tremblay Mark;
Documents	UOW application for HREC approval v7 23/01/2018
Approved:	Response to HREC Review of SUNRISE Pilot Study 28/3/2018 Consent form v7 23/01/2018 Participant information sheet v7 23/01/2018 Ages and Stages questionnaire v7 23/01/2018 WHO STEPS parent questionnaire V7 23/01/2018 Activity monitor instruction sheet v7 23/01/2018 Email re translation of overseas ethics approvals SUNRISE Ethics response
Documents Noted:	Ethics Approval Brazil site Ethics Approval China site

Sites:

Early Childhood Settings located in:

Principal Investigator for Site

Canada

Mark Tremblay

China

Guan Hongyan

South Africa

Catherine Draper

Brazil

Alex Florindos

Papua New Guinea

Bang Pham Nguyen

The HREC has reviewed the research proposal for compliance with the *National Statement on Ethical Conduct in Human Research* and approval of this project is conditional upon your continuing compliance with this document. Compliance is monitored through progress reports; the HREC may also undertake physical monitoring of research.

Approval is granted for a twelve-month period; extension of this approval will be considered on receipt of a progress report **prior to the expiry date**. Extension of approval requires:

- The submission of an annual progress report and a final report on completion of your project.
- Approval by the HREC of any proposed changes to the protocol or investigators.
- Immediate report of serious or unexpected adverse effects on participants.
- Immediate report of unforeseen events that might affect the continued acceptability of the project.

If you have any queries regarding the HREC review process or your ongoing approval please contact the Ethics Unit on 4221 3386 or email rso-ethics@uow.edu.au.

Yours sincerely,

Emma Barkus

Associate Professor Emma Barkus,

Chair, UOW & ISLHD Social Sciences Human Research Ethics Committee

The University of Wollongong and Illawarra and Shoalhaven Local Health District Social Sciences HREC is constituted and functions in accordance with the NHMRC National Statement on Ethical Conduct in Human Research.

Appendix H: Tanzania ethics approval letter



THE UNITED REPUBLIC OF TANZANIA



National Institute for Medical Research
3 Barack Obama Drive
P.O. Box 9653

Il 101 Dar es Salaam

Tel: 255 22 2121400

Fax: 255 22 2121360

E-mail: nimrethics@gmail.com

NIMR/HQ/R.8a/V01. IX/3 8 3 8

Jackline Jema Nusurupia

University of Strathclyde, Glasgow

C/o Dr. Leyna Germana

Tanzania Food and Nutrition Centre (TFNC)

P O Box 922

Dar es Salaam

Permanent Secretary (Health)
Ministry of Health, Community
Development, Gender, Elderly &
Children
Government City Mtumba, Health
Road
P.O. Box 743
40478 Dodoma

12th November 2021

RE: ETHICAL CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled: Compliance with 24-hour movement guidelines in preschool children in Tanzania (Nusurupia J. J. et al.) whose local investigator is Dr. Leyna Germana of Tanzania Food and Nutrition Centre (TFNC), has been granted ethical clearance to be conducted in Tanzania.

The Principal Investigator and supervisor of the study must ensure that the following conditions are fulfilled:

1. Progress report is submitted to the Ministry of Health, Community Development, Gender, Elderly & Children and the National

Institute for Medical Research, Regional and District Medical Officers after every six months.

2. Permission to publish the results is obtained from National Institute for Medical Research.
3. Copies of final publications are made available to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research.
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine as per NIMR Act No. 23 of 1979, PART 111 Section 10(2).

5. Sites: Dar es Salaam region.

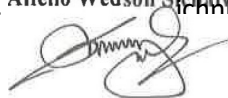
Approval is valid for one year: 12th November 2021 to 11th November 2022

Name: Prof. Y unus Daud Mgaya

Sg  Signature

CHAIR PERSON
MEDICAL RESEARCH
COORDINATING COMMITTEE

Name: Dr. Aifello Wedson Sichulu



CHIEF MEDICAL OFFICER
MINISTRY OF HEALTH, COMMUNITY
DEVELOPMENT, GENDER, ELDERLY &
CHILDREN

CC: Director, Health Services-TAMISEMI,
Dodoma. RMO of Dar es Salaam region.

DMO/DED of liaia district.

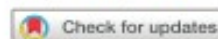
BMJ Open Cross-sectional examination of 24-hour movement behaviours among 3- and 4-year-old children in urban and rural settings in low-income, middle-income and high-income countries: the SUNRISE study protocol

Tony Okely,¹ John J Reilly,² Mark S Tremblay,³ Katharina E Kariippanon,¹ Catherine E Draper,⁴ Asmaa El Hamdouchi,⁵ Alex A Florindo,⁶ Janette P Green,⁷ Hongyan Guan,⁸ Peter T Katzmarzyk,⁹ Himangi Lubree,¹⁰ Bang Nguyen Pham,¹¹ Thomas Suesse,¹² Juana Willumsen,¹³ Mohamed Basheer,¹⁴ Rebecca Calleia,¹⁴ Kar Hau Chong,¹⁴ Penny L Cross,¹⁴ Maria Nacher,¹⁴ Laura Smeets,¹⁴ Ellie Taylor,¹⁴ Chalchisa Abdeta,¹⁵ Nicolas Aguilar-Farias,¹⁶ Aqsa Baig,¹⁷ Jambaldori Bayasgalan,¹⁸ Cecilia H S Chan,¹⁹ P W Prasad Chathurangana,²⁰ Michael Chia,²¹ Fazlollah Ghofranipour,²² Amy S Ha,²³ Mohammad Sorowar Hossain,²⁴ Xanne Janssen,²⁵ Alejandra Jáuregui,²⁶ Piyawat Katewongsa,²⁷ Dong Hoon Kim,²⁸ Thanh Van Kim,²⁹ Denise Koh,³⁰ Anna Kontsevaya,³¹ Germana H Leyna,³² M Lof,^{33,34} Nyaradzai Munambah,³⁵ Tawonga Mwase-Vuma,³⁶ Jackline Nusurupia,³² Aoko Oluwayomi,³⁷ Borja del Pozo-Cruz,³⁸ Jesus del Pozo-Cruz,³⁹ Eva Roos,^{40,41} Asima Shirazi,⁴² Pragya Singh,⁴³ Amanda Staiano,⁹ Adang Suherman,⁴⁴ Chiaki Tanaka,⁴⁵ Hong Kim Tang,⁴⁶ Wei-Peng Teo,²¹ Marites M Tiongco,⁴⁷ Dawn Tladi,⁴⁸ Ali Turab,¹⁷ Sanne L C Veldman,⁴⁹ E Kipling Webster,⁵⁰ Pujitha Wickramasinghe,⁵¹ Dyah Anantalia Widyastari²⁷

To cite: Okely T, Reilly JJ, Tremblay MS, et al. Cross-sectional examination of 24-hour movement behaviours among 3- and 4-year-old children in urban and rural settings in low-income, middle-income and high-income countries: the SUNRISE study protocol. *BMJ Open* 2021;11:e049267. doi:10.1136/bmjopen-2021-049267

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-049267>).

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For numbered affiliations see end of article.

Correspondence to
Tony Okely; tokely@uow.edu.au

ABSTRACT

Introduction 24-hour movement behaviours (physical activity, sedentary behaviour and sleep) during the early years are associated with health and developmental outcomes, prompting the WHO to develop Global guidelines for physical activity, sedentary behaviour and sleep for children under 5 years of age. Prevalence data on 24-hour movement behaviours is lacking, particularly in low-income and middle-income countries (LMICs). This paper describes the development of the *SUNRISE International Study of Movement Behaviours in the Early Years* protocol, designed to address this gap.

Methods and analysis SUNRISE is the first international cross-sectional study that aims to determine the proportion of 3- and 4-year-old children who meet the WHO Global guidelines. The study will assess if proportions differ by gender, urban/rural location and/or socioeconomic status. Executive function, motor skills and adiposity will be assessed and potential correlates of 24-hour movement behaviours examined. Pilot research from 24 countries (14 LMICs) informed the study design and protocol. Data are collected locally by research staff from partnering institutions who are trained throughout the research

Strengths and limitations of this study

- First known multi-country cross-sectional study using new WHO guidelines on physical activity, sedentary behaviour and sleep for children under 5 years of age, informing global efforts to develop culturally specific interventions to improve movement behaviours and ensure young children reach their health and developmental potential.
- Objective, device-based measures of 24-hour movement behaviours and direct measures of executive function, motor skills and adiposity in a sample of urban and rural communities from predominantly low-income and middle-income countries undergoing rapid urbanisation.
- Almost exclusive sampling of children attending Early Childhood Education and Care services may not be representative of the general population in some countries.

Strengths and limitations of this study

- ▶ A generic parent questionnaire may not be sensitive enough to identify the contextual nuances necessary to understand the patterns, prevalence and correlates of movement behaviours.
- ▶ Reliance on data management platforms that require reliable internet connectivity is a challenge in some regions.

process. Piloting of all measures to determine protocol acceptability and feasibility was interrupted by COVID-19 but is nearing completion. At the time of publication 41 countries are participating in the SUNRISE study.

Ethics and dissemination The SUNRISE protocol has received ethics approval from the University of Wollongong, Australia, and in each country by the applicable ethics committees. Approval is also sought from any relevant government departments or organisations. The results will inform global efforts to prevent childhood obesity and ensure young children reach their health and developmental potential. Findings on the correlates of movement behaviours can guide future interventions to improve the movement behaviours in culturally specific ways. Study findings will be disseminated via publications, conference presentations and may contribute to the development of local guidelines and public health interventions.

INTRODUCTION

The early years (defined as <5 years) are arguably the most critical period in life for developing important physical, motor, social and cognitive skills.¹ As a sensitive period of brain development, this period in life provides a window of opportunity where developmental plasticity can be exploited to positively influence the trajectory of a child's life in each of the above developmental areas, and to reduce health inequities.² However, it is also a period for which, despite advances in technology, many gaps still exist in the evidence base.

Consider a young child's physical and motor development in the context of how they move throughout a typical day. It is a combination of sleep, sitting, standing and different intensities of physical activity, the latter mostly in the form of play and other activities of daily living. Little is known about how these behaviours—individually and in combination—influence one another and how they relate to healthy growth and development.³ The dearth of information is even more pronounced in low-income and middle-income countries (LMICs),⁴ many of which are in a period of rapid urbanisation that may further impact the healthy development of these behaviours among this age group.^{5,6}

The WHO has identified the prevention of obesity in young children as one of its key priorities for the 21st century⁵; movement behaviours play a key role in this priority. A specific recommendation from the WHO Report of the Commission on Ending Childhood Obesity (rec 4.12)³ was to develop international guidelines for movement behaviours for the early years (<5 years). This is especially important for LMICs, where awareness of the importance of healthy levels of these behaviours in the early years is low, and benchmarks to determine their prevalence are lacking. In response to this recommendation

and the growing evidence on the relationship between physical activity,¹ sedentary behaviour³ and sleep duration⁷ individually, and in combination,⁴ and health indicators in the early years, the WHO released the first guidelines for physical activity, sedentary behaviours and sleep for children under 5 years of age, in April 2019.⁸ These guidelines are based on an integrated movement behaviour paradigm⁹ and provide recommendations for each of the three movement behaviours (physical activity, sedentary behaviour and sleep) across a 24-hour period, aligning with national recommendations from countries such as Canada¹⁰ and Australia.¹¹

Systematic reviews of studies investigating the relationship between movement behaviours and health indicators have reported that the overwhelming majority were conducted in high-income countries (HICs), even multi-country studies, with very few conducted in LMICs and virtually none comparing HICs with LMICs.^{4,12} It is not known how urbanisation and economic development, particularly in LMICs, is associated with young children's movement behaviours.¹³ Globally, it is estimated that 70% of people will live in cities by 2050 and that most of these people will be children or adolescents.⁶ The majority of this increase in urbanisation will occur in LMICs, and there is concern over how this will be managed. Key challenges particularly in urban environments, such as traffic, pollution, crime, social fears, employment demands, inequitable access to adequate and healthy foods and urban sprawl, may all negatively affect movement behaviours, making it easier for young children to adopt unhealthy levels of these behaviours. In LMICs, there is less likely to be the infrastructure, health and social services, education, economic or policy support to ensure that these core challenges are addressed.⁶

Rapid urbanisation and high population densities reduce green spaces and public playgrounds, worsen air and noise pollution, increase motorised transportation and reduce walkability, which make outdoor physical activity less safe for children.^{5,6,14} Sleep duration and quality might also be affected in settings with high population densities, because children often share bedrooms and beds and are more exposed to electronic media in these spaces.¹⁵ Many families transitioning to cities also desire for their children to have technology-centric lifestyles often seen in HICs, resulting in children engaging in long periods of sedentary screen time that probably replaces active play and increases exposure to marketing of unhealthy foods.¹⁶ Not only does this place children at possible risk of overweight and obesity but healthy child development may be compromised due to lack of play and sleep opportunities.

A systematic review⁴ of studies examining adherence to 24-Hour Movement Guidelines among preschoolers (ages 3 and 4 years), reported that of the nine studies, all from HICs, between 5%–24% met all three of the daily movement guidelines for this age group: (1) at least 180 min of physical activity, of which at least 60 min is energetic play, (2) no more than 1 hour of

sedentary screen time and (3) 10–13 hours of good quality sleep. Prior to the conception of the SUNRISE study there were only two known studies^{17 18} from LMICs that had examined compliance with the 2019 WHO guidelines. A Brazilian study reported that physical activity compliance was the highest at 43%, with 35% and 15% meeting sleep and sedentary screen time recommendations respectively, while only 3% of preschoolers met all three recommendations.¹⁷ A study among Chinese kindergarteners found the proportion of children who met the physical activity, sedentary screen time and sleep guidelines were 65%, 88% and 29%, respectively, with only 15% meeting all three guidelines and 2.7% not meeting any of the guidelines.¹⁸

For these reasons, the *SUNRISE International Study of Movement Behaviours in the Early Years* (<https://sunrise-study.com>) was designed to collect data on the movement behaviours of preschool-aged children, the factors that are related to these behaviours and how the movement behaviours are associated with obesity and other health and developmental outcomes in a large-scale international sample of urban and rural communities. The primary aim of the SUNRISE study is to determine the proportion of 3- and 4-year-old children sampled in participating countries who meet the WHO Global guidelines for physical activity, sedentary and sleep behaviour.⁸ Further, the study aims to determine if these proportions differ by gender, parental education level, urban/rural location and among countries of differing human and economic development.

As a secondary aim, associations between 24-hour movement behaviours and health and development outcomes will be examined. These outcomes include overweight and obesity, gross and fine motor skills and executive function. These secondary aims have been chosen because significant associations have also been found between the composition of 24-hour movement behaviours and indicators of adiposity and bone and skeletal health among preschoolers.⁴ There is also emerging evidence from a number of countries that the prevalence of developmental delay in important domains such as motor and physical devel-

opment are high, around 15% for gross motor skills and up to 32% for fine motor skills.^{19–22} In addition the study seeks to determine potential correlates of 24-hour movement behaviours using a social ecological model, to examine inter-relationships between individuals and the social (eg, family, safety, noise, Early Childhood Education and Care (ECEC)), physical (eg, urban/rural, air quality, outdoor play space) and policy (ECEC policies on food, play, screen time) environment.²³ An overarching goal of SUNRISE is the co-creation of new knowledge and building an international network of researchers interested in 24-hour movement behaviour of young children. This paper aims to describe the protocol of the SUNRISE study,

detailing how the different iterations of the *pilot study phases* have contributed to finalising the methods and measures to be used in the SUNRISE *main study*.

METHODS AND ANALYSIS

Project leadership and management

SUNRISE is guided by an international Leadership Group (see online supplemental table 1) comprising a member from each UN Sustainable Development Goal region (sub-Saharan Africa, Northern Africa and Western Asia, Europe and Northern America, Central and Southern Asia, Eastern and South-Eastern Asia, Oceania, Australia and New Zealand, Latin America and the Caribbean). The group is gender balanced and includes early/mid-career and late-career researchers from low, middle and high-income countries, along with a project statistician and quality assurance expert, WHO representative and an external advisor. The Leadership Group is responsible for developing the protocols for the study, including but not limited to ethical considerations, sampling units and recruitment, governance, budget, data management, training of staff, quality assurance, communications and publications. Video conference meetings are held bimonthly, with the Leadership Executive, made up of three members of the Leadership Group meeting during the alternate months. The SUNRISE Coordinating Centre based at the University of Wollongong (UOW), Australia, is responsible for the overall administration and of the study. This centre comprises a data manager, project, research and equipment officers, a programmer and postdoctoral fellows.

Sample selection

SUNRISE is an international cross-sectional study that aims to recruit approximately 1000 healthy, **gender balanced** children aged 3 and 4 years from each participating country, with equal numbers (500 each) from urban and rural communities representing low-income, middle-income and high-income countries from each major geographical region of the world (see table 1). Countries have been recruited from each of the four levels of the World Bank income classifications (low, middle, high and very high). There has been an effort to spread countries geographically and by income status. Asia and Africa are highly-represented in the sample as 90% of the anticipated increase in the global urban population will occur in these regions over the next 30 years.²⁴

Recruitment of countries into the SUNRISE study has occurred on a continuous basis. Initially countries were recruited by members of the SUNRISE Leadership Group through existing collaborations. The Leadership Group met in Hong Kong in August 2017 to develop the first iteration of the study protocol. A SUNRISE workshop was held at the 2018 International Society of Behavioural Nutrition and Physical Activity meeting in Hong Kong to introduce the study to the international research community and further recruitment occurred at subsequent conferences,



Table 1 SUNRISE participating country characteristics

Country	WHO region	World Bank classification*	Local institution	Location of local institution	Settings for data collection in pilot study	Chief investigator
Botswana	AFRO	Upper-middle income	University of Botswana	Gaborone, Botswana	Urban: Gaborone city Rural: Greater Gaborone district	Dawn Tiadi
Ethiopia	AFRO	Low-income	Adama Hospital Medical College	Adama, Ethiopia	To be determined	Chalchisa Abdeta
Kenya	AFRO	Lower-middle income	Wellness for Greatness, Kenya	Nairobi, Kenya	To be determined	Amosije Moses Oluchiri
Malawi	AFRO	Low-income	Centre for Social Research, University of Malawi	Zomba, Malawi	Urban: Lilongwe, Central Malawi Rural: Karonga, Northern Malawi	Tawonga Mwasa-Vuma
Nigeria	AFRO	Lower-middle income	University of Lagos	Lagos, Nigeria	Urban: Southwest Region (Lagos State) Rural: Southwest Region (Lagos State)	Aoko Oluwayomi
South Africa	AFRO	Upper-middle income	University of the Witwatersrand	Johannesburg, South Africa	Urban: Soweto, Johannesburg, Gauteng province Rural: Sweetwaters, KwaZulu-Natal province	Catherine Draper
Tanzania	AFRO	Lower-middle income	Tanzania Food and Nutrition Center	Dar es Salaam, Nairobi	Urban: Ukonga/Gongolamboto Dar es Salaam Rural: To be determined	Gerrana Leyna Jackline Nusunupia
Zimbabwe	AFRO	Lower-middle income	University of Zimbabwe	Harare, Zimbabwe	Urban: Ruwa, Mashonaland East province Rural: Domboshava, Mashonaland East province	Nyaradzai Munambah
Iran	EMRO	Upper-middle income	Tarbiat Modares University	Tehran, Iran	To be determined	Fazdiah Ghoftanipour
Morocco	EMRO	Lower-middle income	Unité Mixte de Recherche en Nutrition et Alimentation	Rabat, Morocco	Urban: Rabat-Salé-kénitra Region Rural: Rabat-Salé-kénitra Region	Aemna El Hamdouchi
Pakistan	EMRO	Lower-middle income	Precision Health Consultants Global	Karachi, Pakistan	Urban: Karachi West and Central Districts Rural: Larkana, Sindh, Pakistan	Ali Turab Aqsa Baig
United Arab Emirates	EMRO	High-income	University of Wollongong - Dubai	Dubai, UAE	Urban: Dubai, Abu Dhabi, Sharjah, Ras al Khaimah	Asima Shirazi
Finland	EURO	High-income	Folkhälsan Research Center	Helsinki, Finland	Urban: Uusimaa county, Southwest Finland county Rural: Uusimaa county, Southwest Finland county	Eva Roos

Continued

Country	WHO region	World Bank classification*	Local institution	Location of local institution	Settings for data collection in pilot study	Chief investigator
The Netherlands	EURO	High-income	Amsterdam University Medical Centre	Amsterdam, Netherlands	Urban: Amsterdam area Rural: Outside the Randstad area	Sanne Veldman
Poland	EURO	High-income	Institute of Mother and Child	Warsaw, Poland	To be determined	Hanna Nalecz
Russia	EURO	Upper-middle income	National Research Center for Therapy and Preventive Medicine	Moscow, Russia	Urban: Tver Region	Anna Kontseva
Scotland	EURO	High-income	University of Strathclyde	Glasgow, Scotland	Urban: Greater Glasgow Rural: Dumfries and Galloway, Argyll and Bute	John Reilly Xanne Janssen
Spain	EURO	High-income	University of Seville	Seville, Spain	Urban: Valencia and Sevilla provinces Rural: Valencia and Sevilla provinces	Jesus del Pozo Cruz Borja del Pozo Cruz
Sweden	EURO	High-income	Karolinska Institute	Stockholm, Sweden	Urban: Stockholm county Rural: Östergötland county	Marie Löf
Brazil	PAHO	Upper-middle income	University Sao Paulo	Sao Paulo, Brazil	Urban: Sao Paulo municipality Rural: Itabira municipality	Alex Antonio Fiorindo
Canada	PAHO	High-income	Children's Hospital of Eastern Ontario Research Institute	Ottawa, Ontario, Canada	Urban: Ottawa city Rural: Ottawa city surrounds	Mark Tremblay
Chile	PAHO	High-income	Universidad de La Frontera	Temuco, Chile	Urban: Cautin province, Araucania region Rural: Cautin province, Araucania region	Nicolas Aguilar-Farias
Mexico	PAHO	Upper-middle income	Instituto Nacional de Salud Pública	Cuernavaca, Mexico	Urban: Cuernavaca city Rural: Cuernavaca city surroundings	Alejandra Jáuregui
United States	PAHO	High-income	Pennington Biomedical Research Center and Augusta University	Baton Rouge, Louisiana; Augusta, Georgia	Urban: Louisiana, Southeastern Region Rural: Georgia, Southeastern Region	Amanda E. Stalano E. Kipling Webster
Bangladesh	SEARO	Lower-middle income	Biomedical Research Foundation	Dhaka, Bangladesh	Urban: Dhaka district Rural: Dhaka district	Mohammad Sonowar Hossain
India	SEARO	Lower-middle income	Kem Hospital Research Centre	Pune, India	Urban: Pune city Rural: Vadu, Shirur Taluka of Pune district	Himangi Lubree
Indonesia	SEARO	Lower-middle income	Universitas Pendidikan Indonesia	Jawa Barat, Indonesia	Urban: Province of West Java Rural: Province of West Java	Adang Suherman

Continued

Table 1 Continued						
Country	WHO region	World Bank classification*	Local institution	Location of local institution	Settings for data collection in pilot study	Chief investigator
Sri Lanka	SEARO	Upper-middle income	University of Colombo	Colombo, Sri Lanka	Urban: Colombo Rural: Homagama	Pujitha Wickramasinghe Prasad Chathurangana
Thailand	SEARO	Upper-middle income	Mahidol University	Nakhon Pathom, Thailand	Urban: Bangkok region Rural: Central region	Piyawat Katewongsa Dyah Anantalla Widyastani
Australia	WPRO	High-income	Early Start, University of Wollongong	Wollongong, Australia	Urban: Wollongong and Sydney Rural: South Coast NSW	Tony Okely
China	WPRO	Upper-middle income	Capital Institute of Pediatrics	Beijing, China	Urban: Shijingshan district (Beijing) Rural: Huarou district and Fangshan district (Beijing)	Hongyan Guan
Fiji	WPRO	Upper-middle income	Fiji National University	Suva, Fiji	To be determined	Pragya Singh
Hong Kong	WPRO	High-income	The Chinese University of Hong Kong	Shatin, N.T. Hong Kong	Urban: Hong Kong Island, Kowloon and the New Territories	Amy S Ha Cecilia Chan
Japan	WPRO	High-income	J.F. Oberlin University	Tokyo, Japan	Urban: Kyoto and Okinawa prefectures Rural: Nagano and Okinawa prefectures	Chiaki Tanaka
Korea Republic	WPRO	High-income	Korea Institute of Child Care and Education	Seoul, Korea	Urban: Seoul city and Gyeonggi provinces Rural: Gyeonggi and North Chungcheong provinces	Dong Hoon Kim
Malaysia	WPRO	Upper-middle income	Universiti Kebangsaan Malaysia	Bangi, Selangor, Malaysia	Urban: Kuala Lumpur, Nilai, Bangi Rural: Kuala Selangor	Denise Koh
Mongolia	WPRO	Lower-middle income	National Center for Public Health	Ulaanbaatar, Mongolia	Urban: Ulaanbaatar, Khentii Rural: Bayanzurkh, Khentii	Jambaldori Bayasgalan
Papua New Guinea	WPRO	Lower-middle income	Papua New Guinea Institute of Medical Research	Goroka, Papua New Guinea	Urban: Goroka, Eastern Highlands Province Rural: Asaro, Eastern Highlands Province	Bang Nguyen Pham
Philippines	WPRO	Lower-middle income	De La Salle University	Manila, Philippines	Urban: Manila Rural: Region 4A, Region 3	Marites Tiongco
Singapore	WPRO	High-income	National Institute of Education, Nanyang Technological University	Singapore	Urban: Punggol and Sengkang	Michael Chia Wei-Peng Teo

Continued

Table 1 Continued		Settings for data collection in	
World Bank	Location of local	pilot study	Chief investigator
Country	WHO region	Local institution	institution
Vietnam	Lower-middle income	Pham Ngoc Thach University	Ho Chi Minh City.
	of Medicine	Vietnam	
			Urban: District Tân Bình and District 1, Ho Chi Minh city
			Rural: District Bình Chánh and District Nhà Bè, Ho Chi Minh City.

*Obtained from the World Bank. Data—World Bank. Country: Vietnam. Region: SEARO. South-east Asian region; WPRO, Western Pacific region.

through word of mouth and professional and research student networks. Participating countries have therefore either been actively invited or have expressed interest in participating. In each country a partnering institution and local chief investigator (CI) are identified who take responsibility for all aspects of conducting the study at the local level.

Given the vastly differing contexts in which SUNRISE is being conducted, the local CI and research team in each country determine the most appropriate approach to recruiting children of consenting parents/caregivers into the study. This occurs using a convenience cluster sampling approach either through ECEC services, or from the community at a village level. This has occurred in some LMIC rural locations where ECEC services are limited. The sampling frame for each country comprises a geographical area within reasonable travel distance from the CIs institution. If recruitment is conducted through ECEC services, then the primary sampling unit is the ECEC service. In countries where children will be exclusively recruited from both public and private ECEC centres, a maximum of 20 children per centre will be recruited to ensure there is variability within the sample.²⁵ This will result in a minimum of 50 public and/or private centres participating in the main study. Services will not be randomly selected but countries do need to ensure that the sample is broadly representative of the country in terms of sex, socioeconomic backgrounds of parents²⁵ and urban/rural residence.²⁶ All children in the selected ECECs or villages who are within the age range and who can wear an accelerometer are eligible to participate. There are no other exclusion criteria.

Pilot study

To be eligible for participation in the SUNRISE *main study* each country is required to conduct a *pilot study* to assess the feasibility and acceptability of the study protocol, particularly recruitment and data collection methods. For the pilot study, 100 children aged 3 and 4 years are recruited equally from urban and rural settings (50 children from each). Each country is advised to use the national definition of the country to determine what is an urban and rural area. These are typically official definitions. This sample size has been deemed sufficient to test the feasibility of the protocol in each setting. In addition to completing all measures proposed for the main study, the pilot study protocol also includes a survey providing information about the settings in which children spend time and the research team's ability to recruit the required sample in an urban and rural area. Several focus groups are conducted in each country with key stakeholders such as parents and ECEC service staff to discuss the acceptability of the measures and the study protocol. Findings from the focus groups (see [table 2](#)) have been used to modify the protocol and refine the measures. Results from the pilot studies are also being used for subsequent funding applications for the SUNRISE main study at a country level as well as collectively.

Table 2 Focus group and interview findings

Key themes	Main points	Implications for study protocol
Facilitators for childcare centre staff	Study involvement novel and enjoyable.	Confirms the acceptability and appropriateness of the measures and data collection procedures.
Barriers for ECEC service staff	Multiple data collection sessions per participant; keeping track of accelerometers challenging due to large sample; lack of familiarity with wearable technology; limited space within centres and distraction from non-participating children.	During the SUNRISE training, data collectors are advised to administer the assessments tasks to suit each centre programme/schedule, data collector's schedule as required; data collectors trained on device safety and participation ethics.
Parent feedback on questionnaire	Questions were understood and the support of data collectors and translation into local language assisted comprehension; challenges around estimating time spent in PA during time when kids are at the centre; estimation difficult due to seasonality of PA.	Translation of questions into local language as feasible; provide time ranges as response options; adding seasons/time of year to questionnaire; providing link to video instructions on accelerometer use for parents.
Children's overall feedback on participation	Parents and ECEC staff both reported that children enjoyed participating in the study.	Confirms the acceptability and appropriateness of the measures and data collection procedures.
Feedback on accelerometers	Responses to the accelerometers varied. Most found the monitors interesting and children were excited and proud to wear them. Challenges included placement of activPAL monitor on thigh, discomfort, irritation, difficulties dressing, bathing and sleeping, several reports of rashes and wear time compliance.	Use of the activPAL (placed on thigh) was stopped for Phase II and ActiGraph (belt around waist) was used exclusively. For Phase III all children will wear the ActiGraph on the hip.
Feedback on motor skills tasks	Motor skills were seen as age-appropriate and informative for educators about children's strengths and weaknesses. Children enjoyed the tasks.	Confirms the acceptability and appropriateness of the measures and data collection procedures.
Feedback on executive function tasks	The iPad games were generally perceived as fun and age appropriate. Variability among children sustaining interest due to considerable differences in exposure to devices between countries.	Choice of iPad tasks to be appropriate for most children regardless of previous device exposure. Data collectors trained to support children to feel comfortable in using unfamiliar tools.

ECEC, Early Childhood Education and Care; PA, physical activity.

Patient and public involvement

Since the aim of the pilot work is in part to test and refine the study protocol based on local contexts, data collected have been analysed and used to refine the methods and measures over time. Consequently, there have been three distinct pilot phases for this study. A total of 8 countries participated in *Phase I* from March 2018 to July 2019, 12 countries participated in *Phase II* from August 2019 to September 2020 and 21 countries are currently involved in *Phase III* of the pilot study (see [figure 1](#) for map of participating countries). [Table 3](#) highlights the main changes that have been made to the protocol across the three phases. Changes were made based on feedback that was obtained through the focus groups with parents and ECEC service staff as well as feedback from local research teams.

The COVID-19 pandemic has resulted in delays for several countries conducting the pilot study. Consequently,

there will be some countries still trialling the protocol, while others will commence with the main study. Any additional countries wishing to participate in SUNRISE will use the *Phase III* protocol for their pilot study and this will also be used in the main study. Additional questions have been added to the protocol to capture the influence of COVID-19 on the movement behaviours in the ECEC setting (see online supplemental table 2).

Training and capacity building

Face-to-face training sessions organised for all country CIs and key local staff are conducted by the SUNRISE Coordinating Centre in advance of data collection in each country. All staff working on the study receive 2 days of training in all steps of the data collection process with particular emphasis on the administration of all assessments in this age group. Data collectors are certified by trained experts as competent to make the required

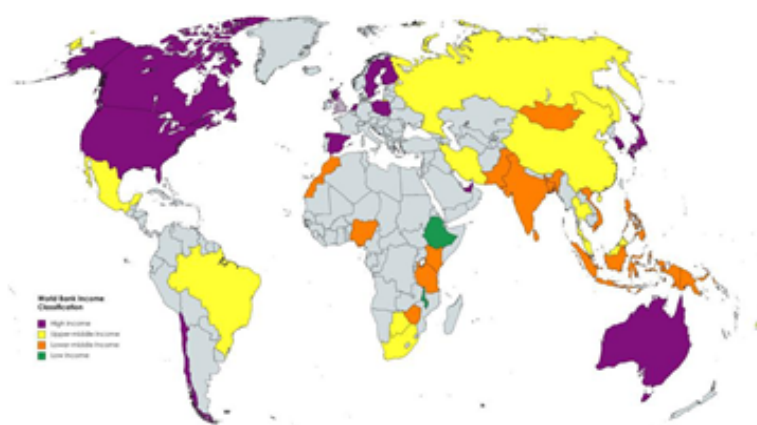


Figure 1 Map of participating countries.

measurements. This involves the watching of online training videos, observation by trainers of data collectors practicing the assessments on children, viewing protocol videos and successfully completing a test on the assessment protocol as part of the face-to-face training by experts. The CIs from each country are mentored throughout the entire research and surveillance process (see below).

Since August 2020, due to ongoing COVID-19-related travel restrictions, the training sessions have been adapted for online delivery. Training sessions for staff in have been held for the SUNRISE teams in Singapore, Russia and Nigeria. To facilitate this, videos have been developed to demonstrate the assessment protocols and practice assessments are conducted over Zoom or recorded and sent to the coordinating centre for feedback. These are publicly available on the SUNRISE YouTube channel (<https://www.youtube.com/channel/UCUgmfAGHO1qW7HV73vDVSLw>).

Measures

The measures described below are those used in *Phase III* of the protocol development.

Primary outcome

Twenty-four-hour movement behaviours (physical activity, sedentary time and sleep) are assessed using accelerometry²⁷ (see table 3 for the types of accelerometers trialled). For the main study, the ActiGraph (GT3X, GT3X+) accelerometer will be used. This waist worn device is the most widely used and extensively validated accelerometer for physical activity, sedentary behaviour²⁸ and sleep assessment.²⁹ A pool of accelerometers is made available for use across countries. Children are asked to wear the device continuously (including sleeping and while engaging in water-based activities such as bathing and swimming) for a minimum of 5 days to get three full days (3×24-hour period) of data. This will provide data on total physical

activity, moderate-to-intensity to vigorous-to-intensity physical activity, total sitting time and total lying time.

In addition, some components of the 24-hour movement behaviours are reported by the primary caregiver on behalf of the participating child. These questions were originally developed based on the recommendations for each behaviour guideline.¹¹ The brief survey, which takes about 15–20 min to complete, asks the caregiver about the child's physical activity (only asked in Phase I), bed, wake and nap times (from which sleep-time is calculated), use of electronic media and restrained sitting (to calculate sedentary time) (see online supplemental table 3).

Secondary outcomes

A range of health and development outcomes will be obtained to assess associations with 24-hour movement behaviours:

Anthropometry—height and weight are measured to the nearest millimetre and kilogram using a portable stadiometer and an electronic, calibrated scale following standardised procedures as per WHO protocols.³⁰

Gross and fine motor skills will be measured via validated activities from the National Institute of Health (NIH) Toolbox.³¹ All measures are scored as outlined by the NIH Toolbox protocol. Five tests are included.

Gross motor skills

►► Children perform a *standing long jump* to determine lower body explosive strength and mobility. A line is marked on the floor and the child stands with their toes just behind the line. The child then jumps with two feet together as far as they can and lands on two feet. The child is given one practice and two test trials. A measurement is taken from the front of the line and the heel of the foot that is closest to the line. The distance is recorded to the nearest centimetre. The average of the distance values recorded is used.



Table 3 Pilot study phases

Countries	Measures	Reasons for modification of protocol
Phase I: 2018–2019		
Brazil Canada China Japan Korea Republic Papua New Guinea South Africa Zimbabwe	Child ▶ Anthropometry—height and weight. ▶ Executive Function Tests—Mr Ant, Go/NoGo, Dimensional Change Card Sort. ▶ Motor Skills (ASQ). ▶ 24-hour movement—ActiGraph, activPAL and Actical. Parent ▶ Parent/caregiver questionnaire. ▶ Focus groups. Centre staff ▶ Focus group.	N/A
Phase II: 2018–ongoing		
Australia/Bangladesh Hong Kong Indonesia Malaysia Morocco Scotland Spain Sri Lanka Sweden USA Vietnam	Child ▶ Anthropometry—height and weight. ▶ Executive Function Tests—Mr Ant, Go/NoGo, Dimensional Change Card Sort. ▶ 24-hour movement behaviour—ActiGraph. Parent ▶ Parent/caregiver questionnaire. ▶ Focus groups. Centre staff ▶ Focus groups.	Eight reports of minor skin irritation following use of the activPAL were reported in Canada, Bangladesh and Australia. Two other studies have also documented minor cases of skin irritation. ^{43, 44} The actiGraph monitor will be used to objectively assess all movement behaviours (ie, sleep, sedentary time and physical activity). Monitor placement will be on the hip. Although the wear compliance rate is not as high as anticipated and there are challenges regarding night-time wear, easy removal of the device and analysis of the sleep data, strategies to resolve these matters are being worked on with the country teams. Parent proxy-report of their child's physical activity was dropped as many parents are not aware of the amount of physical activity their child participates in when at an ECEC service. Physical activity data are exclusively collected via accelerometry. The parent report question on total sleep time was broken down to capture, bed time, wake time and naps as we have found that the main time when children remove the accelerometer is when they go to bed so it provides us with some data on sleep for these children. Also, parent-reported information tends to report the time their child went to bed and got up which is different to the accelerometer which reports the time they went to sleep and woke up. Further parents also report on sedentary screen time as this cannot be assessed by accelerometry.
Phase III: 2019–ongoing		
		Continued

Countries	Measures	Reasons for modification of protocol
Botswana	Child	The Dimensional Change Card Sort was dropped due to the time required to complete the tasks. The developers of the EYT advised that inhibition and working memory are the most salient measures of executive functions to measure in this age group.
Ethiopia	► Movement behaviours – ActiGraph.	Elements from the non-proprietary NIH Toolbox were deemed more culturally feasible and will replace the ASQ to assess motor skills.
India	► Anthropometry – height and weight.	Food habits and eating behaviour questions added to parent/caregiver questionnaire to provide additional context for interpreting anthropometric data.
Indonesia	► Executive Function Tests – Mr Ant, Go/NoGo.	Centre questions added to gain insight into the influences on movement behaviours in the child care centre setting.
Iran	► Motor skills (NIH Toolbox).	
Malawi	Parent	
Mexico	► Parent/caregiver questionnaire.	
Nigeria	► Food habits and eating behaviour questions added to survey.	
Netherlands	Centre staff	
Pakistan	► Focus groups.	
Russia	► Questionnaire.	
Singapore		
Thailand		
Finland		
UAE		
Chile		
Fiji		
Tanzania		
Mongolia		
Philippines		

ASQ, Ages and Stages Questionnaire; CCEC, Early Childhood Education and Care; EYT, Early Years Toolbox; NIH, National Institute of Health.

- A *supine-timed up and go (STuG)* test is used to assess mobility and posture. A line is marked 3 m from a wall (using tape or chalk). A large target (circle or X) is marked on the wall at the child's eye level. The child lies supine (on their back) with their feet (heels) on the line. On 'go' the child is required to get up as quickly as possible, run and touch the target and run back across the 3 m line. The child has one practice and is then given two trials. Timing is started when the assessor says 'Go' and stopped as soon as the child's torso crosses the line. The average time taken to complete the task is used.
- A *one-legged standing balance test* is used to measure posture and balance. The child stands on one leg, with the arms held freely at the side of the body for up to 30 s. The child must keep the standing leg fixed but may keep the free leg in any position as long as it is off the floor. Hooking the free leg around the standing leg is not permitted. Swaying is allowed, and the arms may move from the sides but may not hold the free leg. Timing is started when the free leg leaves the floor. Timing is stopped if the child moves the standing leg or hooks the free leg around the other leg, or touches the free leg with their hands. If the child maintains balance for 30 s the assessment is stopped. The test is then repeated on the other leg. The length of time that the child is balancing on each leg is recorded. The average time spent balancing is used.
- A *handgrip dynamometer* (TKK5825, Grip--A, Takei, Tokyo) is used to assess upper extremity strength. The test measures the capacity of the hand and arm muscles to produce the tension and power necessary for maintaining posture, initiating movement or controlling movement during conditions of loading the musculoskeletal system. The child is required to squeeze the grip dynamometer continuously with full force with their right hand for at least 3 s without letting his/her arms touch their body. The test is then repeated with the left hand. The maximum measure attained is recorded.

Fine motor skills

The 9-hole pegboard test (PAT--A8515, Sammons Preston, Illinois, USA) is used to assess dexterity or manipulation. Dexterity is a central component of hand function and relates to both the speed and accuracy of hand movements. A child is timed picking up nine pegs one at a time and inserting them into the pegboard (31.1 cm × 26.0 cm × 4.3 cm). The test is then repeated with the left hand. The timer begins as soon as the assessor says 'Go' and is stopped as soon as the final peg is placed back in the well in the pegboard.

The 9-hole pegboard test and grip strength test are based on the assessments in the NIH Toolbox Motor Battery (ages 3–6).³¹ The one-legged standing balance test and STuG were recommended as assessments for static balance and mobility (general mobility and loco-motion), respectively. This recommendation was made

by the Motor Domain Group in their proposal for assessment of motor function for mobility and posture for the National Children's Study (USA).³² For assessment of mobility this Group recommended the vertical jump for age 5 onwards. On consultation with the lead author, it was recommended that a standing long jump be used for children under the age of 5. The standing long jump is widely used in motor development assessment batteries for this age group.^{33 34}

Executive function

Inhibition and working memory, two key indicators of cognitive function, will be measured using the validated Early Years Toolbox (EYT).³⁵ Two brief, game-like assessment from the toolbox will be administered via an iPad and scored according to the EYT protocol.

- The *Go/No-Go* task is an assessment of 'inhibition'—the ability to control behavioural urges and impulses. Children are presented with fish and sharks and are instructed to tap the iPad screen whenever they see a Fish ('catch the fish') and refrain from responding when a Shark appears ('avoid the sharks').
- The *Mr Ant* task is an assessment of 'visual-spatial working memory'—the amount of visual information that can be concurrently coordinated in the mind. Children are presented with an image of a cartoon character—Mr Ant—who has a number of coloured dots placed in different spatial locations on his body. After a predetermined amount of time, these dots disappear, and the child is then asked to recall the locations of the dots by tapping the corresponding locations.

Parent questionnaire

In addition to the parent questionnaire on the child's 24-hour movement behaviour, standardised validated questions are asked of parents to assess potential correlates of 24-hour movement behaviour using a social ecological model, to examine inter-relationships between individuals, social, physical and physical environment.²³ This includes questions on the child's dietary diversity,³⁶ eating behaviour and food insecurity³⁷ at the family level. Further, sociodemographic information based on a modified version of the WHO STEPS survey³⁸ is recorded (see online supplemental table 3).

The questions assessing children's movement behaviours were based on the recommendations made by the surveillance subcommittee of the Guideline Development Group for the Australian 24-hour movement behaviour guidelines for the early years in 2017. The committee provided guidance on how to assess the proportion of children meeting the recommendations for each of the movement behaviours. The questionnaire in its entirety has not yet been validated.

ECEC service questionnaire

In settings where recruitment occurs at the ECEC service level, influences on 24-hour movement behaviour are

assessed via a staff questionnaire. Questions cover the services' policies around food provision, the physical activity habits of the children and their sleep behaviour while at the ECEC service, to assess centre-level policy correlates of 24-hour movement behaviours (see online supplemental table 2).

All instruments were assessed for their cultural relevance and appropriateness, and in countries where English is not a first language, the instruments were translated by a native speaker and back-translated to ensure accuracy. Table 4 reports the initial results from the pilot studies including response rates for the main measures.

Outdoor air quality

Pollution levels will be measured at each participating ECEC service or at the village level during data collection using the Plume Labs application. The Plume mobile application, provides real-time pollution level data provided by environmental monitoring networks run by local and national governments around the world. Specifically, the application reports on particulate matter 2.5 (PM_{2.5}), PM₁₀ levels and give an overall air quality index. The purpose of this is to determine whether air quality is related to children's outside physical activity time and intensity during the day.

Data collection procedures

All data are collected by local data collectors in each country. A detailed protocol manual sets out the data collection instruments and procedures. To minimise errors caused by entering data from hard copy to electronic format, and to ensure data transfer efficiency, data are collected and managed using REDCap electronic data capture tools hosted at the UOW, Australia. REDCap (Research Electronic Data Capture) is a secure, web-based application designed to support data capture for research studies, providing: (1) an intuitive interface for validated data entry; (2) audit trails for tracking data manipulation and export procedures; (3) automated export procedures for seamless data downloads to common statistical packages; and (4) procedures for importing data from external sources.^{39 40} One exception is the parent questionnaire, which is either completed by parents on paper or where literacy poses challenges, via interview, with the data entered directly into REDCap by the data collector. The Coordinating Centre loans iPads to participating countries with the REDCap projects and Early Years Toolbox games preloaded onto them.

Initial contact with individual ECEC service or village is made by a member of the local research team in each country. Dates for each service/village visit are then provided to all data collectors and local protocols for entering and exiting each service/village are followed.

As there are several measures to be taken with the children, the following order has been trialled and is recommended to ensure a smooth data collection process, giving children sufficient variability between tasks to sustain their engagement: (1) Executive function

task (Mr Ant), (2) attach ActiGraph accelerometer, (3) measure height and weight, (4) assess gross motor skills, (5) assess fine motor skills and (6) executive function task 2 (GoNoGo). All measures are conducted on 1 day and take approximately 20 min to complete. It is not anticipated that participation in any measure will compromise the results of any subsequent measures.

Data in REDCap can be collected offline. To commence, the participant is allocated their unique study identification number. The consent form must then be completed which allows the remaining data to be collected and entered as per the suggested order. The data are saved as the data collector progresses through the various screens. The accelerometer monitor identification number is also entered to enable linking with the accelerometry data. Once all data have been collected and the iPad is able to be connected to the internet all data are sent to the project's REDCap server. From the server it is transferred to the UOW Coordinating Centre's databases for checking, and analysis. Comprehensive data guidelines that set out the principles, protocols, methods and procedure governing the management, access, use and dissemination of the data have been developed for the study.

Data analysis plan

Data on participant attributes such as demographic and anthropometric and movement behaviours will be summarised separately for boys and girls, and across urban and rural settings, as counts and percentages for categorical variables and means and SD for continuous variables. Given that the primary aim of the SUNRISE study is to determine the proportion of 3- and 4-year-old children sampled in participating countries who meet the WHO Global guidelines for physical activity, sedentary and sleep behaviour, prevalence estimates analysis will be conducted. We will also report the proportions who meet any combinations of the guidelines, including those who do not meet any recommendations. Linear and generalised linear models will be used for association analysis to assess whether associations exist (i) between meeting all (or any of the) guidelines and factors, such as sex (primary aims) and (ii) between health and development outcomes and 24-hour movement behaviours (secondary aims). The models will be covariate-adjusted, and treat ECEC service/villages within site and children within ECEC service/villages as well as ECEC service/villages within countries as random effects for all analyses. Statistical significance will be defined as $p < 0.05$ with appropriate adjustments for multi-testing.

Main study sample size calculation

Data obtained from SUNRISE pilot studies from 17 countries, showed that the proportions of children meeting all components of the WHO Global guidelines varied across countries from 2.3% to 42.7% with a mean country proportion of 21.0%. These proportions also differed within many countries when comparing rural with urban

Table 4 Response rates from pilot studies as at article submission date

Country	Response rate	Total # of children	Mean # of children per ECEC	# of children with ≥1 days of '24 hours' data	% of children with ≥1 days of '24 hours' data	Response rates parent survey (%)	Gross motor skills (%)	Fine motor skills (%)	EYT (Mr Ang) (%)	EYT (GoNoGo) (%)	# of focus groups	# of interviews
Australia	89.2%	91	13.0	56	62.9	78.0	100.0	100.0	100.0	98.9	2	
Bangladesh	97.0%	64	16.0	57	89.1	98.4	98.4	98.4	93.8	79.7	3	
Brazil†		81	40.5	59	76.6	76.5	90.1	90.1	84.0	86.4	1	
Canada	17.6%	106	6.6	86	82.7	96.2	100.0	100.0	97.2	90.6		69
China	84.9%	213	71.0	153	77.3	90.1	87.3	87.3	85.4	84.5	3	
Hong Kong	31.6%	89	22.3	88	86.4	100.0	100.0	100.0	100.0	100.0	1	
Indonesia - Phase II*		101	6.7	17	17.3	98.0	97.0	97.0	81.2	88.1	0	
Indonesia - Phase III*		58	6.4	36	65.5	74.1	93.1	93.1	60.3	70.7	9	
Japan	43.7%	111	10.1	101	91.0	96.4	100.0	100.0	95.5	98.2	7	
Korea Republic†		45	4.1			93.3	100.0	97.8	91.1	91.1	0	
Malaysia	70.0%	135	5.6	82	64.1	100.0	97.8	97.8	96.3	96.3	3	
Papua New Guinea‡	62.9%	100	7.7	83	85.6	100.0	100.0	100.0	95.0	98.0	20	
South Africa*		88	12.6	77	89.5	96.6	97.7	97.7	97.7	100.0	3	
Spain	28.0%	85	10.6	77	96.3	97.6	91.8	91.8	84.7	87.1	0	
Sri Lanka	49.1%	105	13.1	99	95.2	100.0	100.0	100.0	99.0	100.0	0	
Sweden**		100	8.3	72	75.0	98.0	100.0	100.0	99.0	98.0	1	
Vietnam	42.1%	137	34.3	112	83.6	161.2	98.5	98.5	95.6	95.6	1	
Zimbabwe†	56.1%	82	16.4			90.2	95.1	95.1	90.2	92.7	0	
India*		52	52	42	80.8	98.1	100.0	100.0	98.1	100.0		50
Pakistan*		24	12.0	19	82.6	100.0	95.8	95.8	79.2	79.2	0	

*The response rate could not be calculated in these countries as the denominator was unknown.

†Only the activity EYFAL was pilot tested in these countries.

‡Data collected at the village level.

ECEC, Early Childhood Education and Care; EYT, Early Years Toolbox.

areas. The mean absolute difference in the proportion between rural and urban was 9.6%.

The power calculation is based on achieving 80% power and a 5% significance level for each country and assuming a rate of 21% of meeting all three guidelines and detecting a difference of 9.6% in either direction (two-sided) between urban and rural and based on an equal allocation to both rural and urban settings. This provides an effect size of 0.23 (small effect),⁴¹ and results in a sample size of $n=558$ per country.

When assuming a response rate of 76% (based on average response rate in the 16 pilot studies), the required sample size increases to $n=734$. The sampling of the main study will be partly based on cluster sampling (usually childcare centres). The intra-class correlation (ICC) was estimated for each country, however, due to low pilot sample sizes in each country, the country-specific ICC estimates vary widely and are unreliable. Instead, we combined countries and estimated the ICC after controlling for country-specific effects. The resulting ICC estimate was zero. However, a zero ICC might be too optimistic (resulting in smaller sample size) for the main study, possibly resulting in too low power, if the ICC is indeed positive in the main study. To be conservative, we used an ICC estimate of 0.022 from the PATH study.⁴² Taking this value and assuming data to be collected on 20 children (on average) per child care centre when 25 are recruited (on average), the sample size of $n=735$ is further increased to approximately $n=1000$. This sample size is also sufficiently large to have a margin of error of at most 5% for a 95% CI for the proportion of meeting all three guidelines for each country and for both rural and urban populations when centred around 21%.

Ethics and dissemination

Ethics approval

The overarching protocols for the pilot study (2018/044) and the main study (2019/378) have been approved by the UOW, Australia, Human Research Ethics Committee. The protocol is also approved in each country by the ethics committees at the participating institutions of each CI, as applicable (see online supplemental table 4). In addition, approval is sought from any government departments or organisations who oversee relevant settings in the different countries. Participant information sheets, consent forms and questionnaires are translated and back translated, as necessary, into the local language of each country following approved procedures of the local institutions. Parental consent is obtained for all participating children.

Quality assurance of data collection, storage and management

This component of the project has been supported by the Australian Health Services Research Institute at the UOW. A comprehensive *Research Data Management Plan* that sets out the principles and protocols governing the management, access, use and dissemination of the data has been developed. The data are securely stored in databases on

password-protected servers at the UOW. All participating countries retain ownership of their data. The terms of collaboration are detailed in a Collaboration Agreement that is entered into between the UOW and the participating institutions of each CI. This collaboration agreement also details intellectual property issues, data use, confidentiality, privacy, loaning of equipment and the roles and responsibilities of each party. The agreement is reviewed by each country's legal representative and executed by both the participating country's authorised representative and the UOW authorised representative, prior to training in each country.

Global impact of SUNRISE

As the first-known international study of movement behaviours in the early years, SUNRISE will make a significant contribution to our understanding of the physical activity, sedentary behaviour and sleep patterns of preschool aged children. Further, SUNRISE will investigate if these behaviours differ by gender, parental education level, urban/rural location and among countries of differing human and economic development, and how these compare to current global movement behaviour guidelines. The study will also enable analysis of associations between movement behaviours and health and developmental indicators and provide evidence on potential correlates of movement behaviours among young children.

A considerable strength of the study is the breadth of the resulting data set. SUNRISE data will be collected in urban and rural settings in 39 countries, from every WHO region, with up to 60% of participating countries being of low-income or middle-income, resulting in a truly unique data set. A further strength of the study is the extensive pilot testing of the protocol (as described in this article) which has resulted in a scientifically robust, culturally appropriate, feasible, standardised protocol. The strong data management and capacity building elements incorporated into the design of the study are a further strength.

In conclusion, the results to be obtained by SUNRISE, particularly on the correlates of movement behaviours, have the potential to inform the development of future interventions to improve the movement behaviours in culturally specific ways across a diverse range of settings. The collaborative international network of researchers and practitioners brought together by this study will be instrumental in driving this important agenda further and will no doubt make considerable contributions to ensuring that young children reach their full developmental potential.

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Appendix J: Pictures

Picture A: One leg standing test.



Picture B: Grip strength dynamometer test



Picture C: Nursery school environment



Picture D: Guidelines printed on the childrens incetives bag



Picture E: Children's incentives



Picture F: Standing long jump test



Picture G: Nursery Kitchen



Picture H: Nursery play



Appendix M: Published article for chapter 4 in journal published format

Child: Care, Health and Development

WILEY

 RESEARCH ARTICLE 

**Urban Versus Rural Differences in Meeting 24-h
Movement Behaviour Guidelines Among 3–4-Year-Olds: An**

Analysis of SUNRISE Pilot Study Data From 10 Low- and Middle-Income Countries

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Keywords: 24-h | LMICs | movement behaviours | physical activity | preschool children | sleep

ABSTRACT

Background: Insufficient physical activity, excessive screen time and short sleep duration among young children are global public health concerns; however, data on prevalence of meeting World Health Organisation 24-h movement behaviour guidelines for 3–4-year-old children in low- and middle-income countries (LMICs) are limited, and it is unknown whether urbanisation is related to young children's movement behaviours. The present study examined differences in prevalence of meeting 24-h movement behaviour guidelines among 3–4-year-old children living in urban versus rural settings in LMICs.

Methods: The SUNRISE Study recruited 429, 3–4-year-old child/parent dyads from 10 LMICs. Children wore activPAL accelerometers continuously for at least 48 h to assess their physical activity and sleep duration. Screen time and time spent restrained

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were assessed via parent questionnaire. Differences in prevalence of meeting guidelines between urban- and rural-dwelling children were examined using chi-square tests.

Results: Physical activity guidelines were met by 17% of children (14% urban vs. 18% rural), sleep guidelines by 57% (61% urban vs. 54% rural), screen time guidelines by 50% (50% urban vs. 50% rural), restrained guidelines by 84% (81% urban vs. 86% rural) and all guidelines combined by 4% (4% urban vs. 4% rural). We found no significant differences in meeting the guidelines between urban and rural areas.

Conclusions: Only a small proportion of children in both rural and urban settings met the WHO 24-h movement guidelines. Strategies to improve movement behaviours in LMICs should consider including both rural and urban settings.

1| Background

Time spent in physical activity, sedentary behaviours (including screen time) and sleep (the 24-h movement behaviours) are crucial to health and development in early life (World Health Organisation (WHO), 2019). During the launch of the World Health Organisation (WHO) guidelines on physical activity, sedentary behaviour and sleep for under 5 s in 2019 (World Health Organisation (WHO), 2019), the WHO Director General Dr Tedros Adhanom Ghebreyesus said that 'Early childhood is a period of rapid development when family lifestyles can be adapted to boost health gains'. Improving physical activity, reducing sedentary time and ensuring adequate sleep among young children can improve their physical and mental health in the short- and long-term and help prevent obesity and associated diseases (World Health Organisation (WHO), 2019). Obesity can affect the immediate and long-term health of a child, educational attainment and quality of life (World Health Organisation (WHO) 2016).

The WHO guidelines (World Health Organisation (WHO), 2019) recommended that children aged 3–4 years, in a period of 24 h, should (i) spend 180 min in physical activity (of which at least 60 min should be moderate- to vigorous-intensity physical activity, MVPA); (ii) not be restrained for more than an hour at a time; (iii) not engage in more than 1 h of sedentary screen time; and (iv) have 10–13 h of good quality sleep. To date, various countries have developed, adopted or adapted guidelines for the early years to fit their socio-economic and cultural circumstances. Canada was the first country to develop combined/integrated 24-h movement behaviour guidelines for the early years in 2017 (Tremblay et al. 2017). This was soon followed by Australia (Okely et al. 2017) and New Zealand (New Zealand Ministry of Health 2017). The United Kingdom (UK) guideline development group recommended that 24-h movement behaviour guidelines be adopted for the under 5 s, but the UK Health Departments only adopted the guidelines for total physical activity (TPA) and MVPA (Reilly et al. 2019). Among low- and middle-income countries (LMICs), South Africa (Draper et al. 2020) and Thailand (Khamput et al. 2017) have also developed 24-h movement behaviour guidelines for the under 5 s.

Since the release of the WHO 24-h movement guidelines for under 5 s in 2019 (World Health Organisation (WHO) 2019),

research has shown that the prevalence of preschool children meeting these guidelines may be low. For example, a study from Canada (Chaput et al. 2017) found that only 13% of preschool-aged children met the 24-h movement behaviour guidelines, and only around 14% of children from Australia (Cliff et al. 2017). Nevertheless, because most of these studies on the prevalence of meeting the WHO movement behaviour guidelines for 3–4-year-olds were retrospective, that is, not specifically designed to answer research questions about prevalence, it is possible that studies designed to estimate prevalence and differences in prevalence (e.g., between urban- and rural- dwelling children)

might produce different results. In addition, most previous studies were conducted in high-income countries (HICs) and very few studies have been conducted in LMICs. For example, in a recent systematic review and meta-analysis of children under 5 years of age (Feng et al. 2021), only one study out of 11 was conducted in LMICs. More recently, some LMICs have begun to conduct research in this area following the development of the International Study of Movement Behaviour in Early Years (SUNRISE) (Okely et al. 2021). SUNRISE was developed with the major aim of determining the proportion of preschool children (3–4-year-olds) meeting the WHO 24-h movement behaviour guidelines for the early years and identifying differences in prevalence of meeting guidelines by factors such as age, sex and urban versus rural living (Okely et al. 2021).

The Behavioural Epidemiology Framework (Sallis, Owen, and Fotheringham 2000) presents a conceptual basis for studying prevalence and correlates of health behaviours (e.g., meeting health behaviour guidelines), so that interventions aimed at improving health behaviours can be developed. This framework notes the importance of identifying if health behaviour guidelines are typically being met or not and emphasises the need to determine which risk factors (e.g., socio-environmental factors such as sex, age, season and socio-economic status [SES]) are related to not meeting guidelines (Sallis, Owen, and Fotheringham 2000). Evidence on the correlates of meeting or not meeting the WHO guidelines will help in determining high-risk groups and provide guidance on how to equitably promote healthier levels of physical activity, sedentary behaviour and sleep in early childhood. At present, it is unclear whether there are marked differences in meeting the 24-h movement behaviour guidelines between children from urban versus rural environments in LMICs (Okely et al. 2021). In sub-Saharan Africa, for example, our previous systematic review found negligible evidence on time spent in the movement behaviours in young children from both urban and rural settings (Nusurupia, Reilly, and Janssen 2021). Some studies (Manyanga et al. 2019; Swindell et al. 2022; Prista et al. 2009) in LMICs have found differences in physical activity between school-aged children and adolescents living in urban and rural settings but whether such differences exist at younger ages, and whether they apply to

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the other movement behaviours, is unknown. Therefore, the aim of the present study was to examine in an international cross-sectional study whether urban versus rural living location was associated with the probability of meeting the WHO movement behaviour guidelines in LMICs.

1 Methods

1.1 | Study Setting

This study used data from 10 countries classified as LMICs based on their economic status using World Bank categories (The World Bank 2024). Participants in the present study were recruited as part of the first and second pilot phases of the SUNRISE Study (Okely et al. 2021; The SUNRISE Study 2024). To participate, children needed to be between the ages of 3.0 and 4.9 years and to be in apparently good health; children with disabilities or other chronic diseases were excluded. In each of the participating SUNRISE countries, a pilot study took place with the aim of recruiting approximately 100 children, with approximately equal numbers of boys and girls and equal numbers from urban and rural settings. Participating countries in the current study were all the SUNRISE LMICs that had completed their feasibility study and used activPAL monitors (PAL Technologies, Glasgow) prior to the COVID-19 pandemic in 2020. The countries included were Bangladesh (lower middle income), Zimbabwe (lower middle income), Vietnam (lower middle income), Sri Lanka (lower middle income), Indonesia (lower middle income), Papua New Guinea (lower middle income), Brazil (upper middle income), China (upper middle income), Malaysia (upper middle income) and South Africa (upper middle income) (The World Bank 2024). The SUNRISE protocol demonstrated a high (Okely et al. 2021) level of feasibility and pilot study data were combined for the present secondary analysis.

1.2 | Measurements of Physical Activity and Sleep

activPAL accelerometers were used to objectively assess the child's time spent asleep, in physical activity and time spent sedentary. The activPAL is currently the only single device that permits measurement of time spent in all of these movement behaviours. The use of activPAL accelerometers in the SUNRISE Study was based on their high reliability and validity for measurement of posture allocation (i.e., lying, sitting and standing) and time spent in physical activity in preschool children (Davies et al. 2012). There are, however, inconsistent results when it comes to the practical utility of the activPAL in children aged 3–4 years: with some showing better compliance than others and a study of high validity for TPA and MVPA, but for an older model of activPAL. It is therefore unclear how accurate the activPAL model used is for the measurement of MVPA and so MVPA was not measured in the present study.

Children were asked to wear the activPAL on their right thigh for 5 days to get at least two full valid days (a valid day was defined as having 24-h of valid data with a minimum of 6 h of valid wear time during waking hours) of data. An output file (event file) was created using the PAL batch software (v8.10: PAL Technologies Ltd, Glasgow) and the standard PAL analysis algorithm (VANE). Full details of measurement procedures are available in the SUNRISE Study protocol paper (Okely et al. 2021) and website (The SUNRISE Study 2024).

Time spent moving (referred to as 'stepping' in activPAL output), referred to as TPA from here onwards because it pro-

vides a valid measure of TPA in 3–4-year-old children (Davies et al. 2012), and time spent sleeping were calculated via a custom-made MATLAB program. TPA and sleep time were calculated for each day and then averaged across all valid days for each child. Children were categorised as meeting the TPA guideline if they had at least 180 min of TPA averaged over all included days. Children who spent an average of 10 to 13 h of sleeping were classified as meeting the sleep guideline. Total daily step counts were also measured by activPAL as these provide a valid proxy measure of meeting (at least 11 500 steps/day) or not meeting (less than 11 500 steps/day) the WHO guideline for total time spent in physical activity in 3–4-year olds (Mwase-Vuma et al. 2022).

1.3 | Measurement of Screen Time and Restrained Sitting

Parents were asked to complete a questionnaire reporting the total time their child spent using digital screens per day (minutes/day) (Sallis, Owen, and Fotheringham 2000). All questionnaires were translated into their respective local languages and administered by trained enumerators in each country for clarity. Parents were also asked to report when their child was restrained for more than 1 h at a time (e.g., in a car seat or stroller) (Sallis, Owen, and Fotheringham 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 1 h at a time restrained were classified as meeting the restrained guidelines.

1.4 | Urban Versus Rural Environment

For categorisation of rural/urban setting, each country provided its own definition as there is no global definition of urban versus rural setting. Based on each country's classification, we then dichotomised the samples as urban or rural (Sallis, Owen, and Fotheringham 2000) and combined the data to make an urban group and rural group as shown in Data S1. Several control variables were captured through the parental questionnaire in the SUNRISE Study (Sallis, Owen, and Fotheringham 2000) including age, sex and SES. SES was derived from parental education level, dichotomised as high (tertiary education or above) or low (secondary/high school or below) education. The SUNRISE Study parent questionnaire was based on a modified version of the WHO STEPwise approach to surveillance (STEPS) questionnaire (World Health Organisation (WHO) 2011; Okely et al. 2021).

1.5 | Statistical Analysis

All statistical analyses were conducted using SPSS version 28. Participant characteristics are presented using descriptive data analysis, means (SDs) or frequencies (percentages) as appropriate.

Chi-square (χ^2) (categorical variables) and unpaired *t*-tests

(continuous variables) were used to examine potential differences between children in urban and rural settings. Using univariate logistic regression analysis, we also examined differences in meeting movement behaviours guidelines between samples from urban and rural settings while controlling for age, sex and SES. A significant association was defined as a p -value of < 0.05 for independent sample tests. Using univariate ANOVAs, means were compared between urban and rural settings while controlling for sex, age and SES. Dependent variables were movement behaviours (total sitting time, total standing time, TPA, total steps taken, total sleep time and total screen time).

2 | Results

1.1 | Characteristics of Study Participants

A total of 601 participants consented to participate in the study; 172 children were excluded from the analysis for either having less than two valid days of activPAL data or being outside the age range of 3.0–4.9 years. As a result, a total of 429 children (194 from rural areas and 235 from urban areas) were included in the final analysis.

Table 1 shows the descriptive characteristics of the sample. The mean age was 4.3 (0.4) years, 218 were boys (51%) and 175 of the parents had high SES (41%). Out of the 429 children, 235 were living in rural areas (55%). Data S2 provides descriptive characteristics of 497 children who had completed 1 day's worth of accelerometer data for analysis (i.e., 1×24 h period).

1.2 | Meeting Individual Movement Behaviour Guidelines in Urban and Rural Settings

Table 2 shows the percentage of children meeting and not meeting the guidelines in urban and rural settings. No significant differences were found in the prevalence of meeting any of the movement guidelines between urban and rural participants.

1.3 | A Comparison of Continuous Variables Using Univariate Analysis of Variance

Children in urban settings sat for a longer period of time than those in rural settings after controlling for sex, age and SES ($F(1, 382) = 4.94, p = 0.027$).

There was no significant difference between urban versus rural settings for total standing time ($F(1, 392) = 0.622, p = 0.431$), TPA ($F(1, 392) = 1.554, p = 0.213$), total steps taken ($F(1, 392) = 2.068, p = 0.151$), time spent in sleep ($F(1, 392) = 1.033, p = 0.310$) or screen time ($F(1, 383) = 0.402, p = 0.526$), after controlling for sex, age and SES.

1.4 | Differences in Meeting Behaviour Guidelines Between Urban and Rural Settings

After controlling for sex, age and SES, urban versus rural setting was not significantly associated with meeting the physical activity guidelines (OR = 1.29, 95% CI = 0.71–2.36, $p = 0.40$), screen time guidelines (OR = 1.17, 95% CI = 0.77–1.78, $p = 0.47$), restrained time guidelines (OR = 1.35, 95% CI = 0.78–2.33, $p = 0.28$) or meeting all the guidelines (OR = 0.97, 95% CI = 0.31–3.00, $p = 0.95$). However, meeting the sleep time guideline was close to statistical significance (OR = 0.66, 95% CI = 0.43–1.00, $p = 0.05$), with rural children being less likely to meet the sleep time guidelines compared with those living in urban areas.

TABLE 1 | Descriptive characteristics mean (SD).

Variables	All (<i>n</i> = 429)	Urban (<i>n</i> = 194)	Rural (<i>n</i> = 235)	<i>p</i> ^c
Age years	4.3 (0.4)	4.3 (0.4)	4.4 (0.4)	0.005
Sex boys % (n)	51 (218)	55 (106)	48 (112)	0.174
Socio-economic status ^a high % (n)	41 (175)	58 (106)	32 (69)	< 0.001
Total sitting time minutes/day	442 (96)	459 (92)	429 (98)	0.001
Total standing time minutes/day	210 (59)	205 (59)	216 (58)	0.057
Total physical activity minutes/day	137 (52)	132 (52)	142 (52)	0.050
Total steps/day	10 338 (4425)	9830 (4281)	10 757 (4506)	0.031
Total sleep time minutes/day	649 (97)	644 (83)	654 (106)	0.322
Screen time minutes/day ^b	104 (94)	104 (91)	104 (96)	0.997

Note: SES was measured using the level of parental education. Abbreviation: SD = standard deviation.

^a*n* = 175.

^b*n* = 419.

^c*p*-value for independent *t*-test or chi-square.

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TABLE 2 | Prevalence of meeting the guidelines in rural and urban areas % (*n*).

Variables	Total meeting guideline for both settings (<i>n</i> = 429)	Urban (<i>n</i> = 194)	Rural (<i>n</i> = 235)	<i>p</i>
Meeting the total physical activity guideline	17 (71)	14 (28)	18% (43)	0.284
Meeting sleep guideline	57 (244)	61 (118)	54 (126)	0.134
Meeting screen time guideline ^a	50 (211)	50 (96)	50 (115)	0.971
Meeting restrained guideline	84 (359)	81 (157)	86 (202)	0.161
Meeting all the guidelines ^a	4 (17)	4 (7)	4 (10)	0.709

^a*n* = 419; *p*-value for chi-square.

2 | Discussion

2.1 | Main Findings

This study aimed to investigate whether setting (urban vs. rural) was associated with meeting the WHO 2019 movement behaviour guidelines in 3–4-year-olds from LMICs. We found that the majority of children from LMICs did not meet the WHO 24-h movement guidelines and urban versus rural differences in prevalence of meeting guidelines were small. The present study suggests that not meeting the movement behaviour guidelines might be common among young children in many LMICs, even in rural settings. If confirmed by larger future studies, then research and surveillance with young children in 3–4-year-olds globally might need to have more of a focus on rural settings.

2.2 | What Is Already Known on This Topic?

Health and development are profoundly impacted by movement behaviours during the early years (World Health Organisation (WHO) 2019; Okely et al. 2021), but the published evidence comes mostly from HICs (Santos et al. 2017; De Craemer et al. 2018), and there is a dearth of evidence on urban–rural differences in the movement behaviours in LMICs.

2.3 | What This Study Adds

The prevalence of meeting 24-h movement behaviour guidelines was low and did not differ significantly between urban and rural settings. Despite perceptions that young children are naturally active (Wachira 2021), the present study revealed low levels of physical activity and high screen time among both urban- and rural-dwelling children, similar to findings in HICs (Kabali et al. 2015; Hinkley et al. 2018). These findings raise concerns regarding health and development impacts, including longer term implications for NCD prevention (Saunders and Vallance 2017; Poitras et al. 2017), highlighting the possible need for initiatives aimed at increasing physical activity and reducing screen time among young children. Generally, urban environments are associated with more sedentary lifestyles and higher rates of obesity among children because of factors such as increased screen time and limited access to safe outdoor spaces for physical activity (Swindell et al. 2022; Ojiambo et al. 2012). On the other hand, rural settings may have more opportunities for physical activity because of active transportation and greater accessibility of open spaces. However, the present study found negligible differences in movement behaviours between rural and urban settings in 3–4-year-olds. This similarity might be due to the physical activity transition, which is characterised by declining physical activity and increasing sedentary time as countries experience economic development. The present study suggests that this transition may be now occurring in both rural and urban settings of the LMICs, resulting in smaller

differences between these settings compared with what might have been observed prior to the transition (Muthuri et al. 2014; Katzmarzyk and Mason 2009).

Despite these trends, rural populations are often underrepresented in global movement behaviour surveillance, particularly in LMICs (Reilly et al. 2022). Most studies focus on urban samples and how urbanisation has impacted health and development. This may be due to logistical challenges in conducting surveillance in rural areas and an assumption that urban settings face more significant issues related to movement behaviours. The present study is consistent with previous criticism (Aubert et al. 2021) that future surveillance of movement behaviours should encompass both rural and urban settings. A more comprehensive understanding of movement behaviour differences between settings will enable LMICs to enhance their public health policies and interventions, better addressing the noncommunicable disease crisis and the ongoing physical activity transition.

Future research should explore the determinants of these movement behaviours in urban and rural settings in LMICs so that intervention can be developed. Such research should consider ‘upstream’ determinants such as air pollution and safety (road safety and crime). Further research will be needed to better understand the influences on movement behaviours in LMICs and how they vary between and within both urban and rural settings to ensure that future interventions can be appropriately informed and tailored to the challenges faced by these communities.

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4.4 | Strength and Limitations of the Present Study

There are several strengths of the present study. First, it was a novel study in LMICs as noted above. Second, the present study used the SUNRISE protocol, which has proven practical and culturally appropriate for LMICs, and movement behaviours were objectively measured with the same device (Okely et al. 2021). Third, most previous studies focused on individual movement behaviours, whereas the present study included all of the movement behaviours, with objective measurement of time spent in physical activity, sedentary behaviour and sleep. Finally, a novel aspect of the study was the comparison between rural and urban settings in early childhood and in LMICs.

However, the present study had some limitations that should also be noted. First, convenience sampling was sufficient for feasibility testing in the SUNRISE pilot studies, but larger and more representative samples will be required to obtain more precise estimates of the prevalence of meeting movement behaviour guidelines—the SUNRISE ‘main studies’ (Okely et al. 2021) are intended to do just that in future. Second, having

device-measured time spent in physical activity and sleep were major strengths, but some variables can only be measured by parent proxy reports at the moment (screen time, restrained time), and there was no alternative method. Third, there was a variation in the definition of rural and urban settings depending on the local context of the country, which may have influenced the interpretation and generalisability of the results. Although future studies, such as the SUNRISE main study, will need to address these issues and refine methodologies for defining urban and rural contexts, this study identified a knowledge gap that still needs to be addressed.

The present study was not powered to make comparisons between two groups (i.e., children living in rural and urban settings) as sample size was fixed by the number of study participants and number of participating LMICs available at the time, but the present study should assist future power calculations. In addition, as noted above, data on movement behaviours from 3–4-year-olds in LMICs is extremely scarce and so the value of the present study lies in adding to a very limited evidence base and providing preliminary data to inform future larger and more robust studies. The preliminary results of the current study suggest that differences between groups might be small. Further larger studies will be needed to confirm our findings but also to examine the reasons for any differences or lack of differences between urban and rural settings.

The SUNRISE Study (Okely et al. 2021)—funding permitting—will move on to larger scale studies that test for urban and rural differences more definitively across a range of different LMICs. Finally, the activPal model used in the present study provides valid measures of TPA (Davies et al. 2012) but has not yet been validated for measurement of MVPA in this age group, but the low levels of TPA observed in the present study suggest that levels of MVPA were probably also low.]

Conclusion

Only a small proportion of LMIC children who lived in both rural and urban settings met the individual and combined movement guidelines in the present study. The present study suggests that there is a need to include both rural and urban settings in future public health surveillance of movement behaviours and in mitigation strategies for the physical activity transition in LMICs.

Author Contributions

Jackline J. Nusrupia: conceptualization, methodology, writing – original draft, writing – review and editing, formal analysis, data curation, visualization. **Leyna H. Germana:** conceptualization, su-

pervision, writing – review and editing. **Pujitha Wickramasinghe:** validation, writing – review and editing, investigation. **Hong K. Tang:** validation, writing – review and editing, investigation. **Nyaradzai Munambah:** investigation, validation, writing – review and editing. **Mohammad S. Hossain:** investigation, validation, writing – review and editing. **Pham Bang:** investigation, methodology, validation, writing – review and editing. **Hongyan Guan:** investigation, validation, writing – review and editing. **Alex Antonio Florindo:** investigation, validation, writing – review and editing. **Catherine E. Draper:** investigation, validation, writing – review and editing. **Denise Koh:** investigation, validation, writing – review and editing. **Kuston Sultoni:** investigation, validation, writing – review and editing. **Anthony D. Okely:** investigation, validation, writing – review and editing. **Mark S. Tremblay:** investigation, writing – review and editing, validation. **Xanne Janssen:** conceptualization, writing – original draft, methodology, writing – review and editing, formal analysis, data curation, supervision, visualization. **John J. Reilly:** conceptualization, writing – original draft, methodology, writing – review and editing, formal analysis, data curation, supervision, visualization.

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Ethics Statement

Ethical approval was obtained from the University of Wollongong, Australia (ref: 2018/044) and in each individual participating country through local ethical review authorities. Parents/guardians provided informed consent for their child's participation in each country.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.

Appendix N: Abstract Book: The Regional Non-Communicable Diseases Scientific Conference



Results: Among 494 patients with hydrocele due to LF analyzed, 214 (43.23%) had hypertension. Patients aged 45 years and above had a high risk (adjusted prevalence ratio (APR) 2.30, 95% CI:1.18-4.46) of developing HTN. Being married was associated with HTN as compared to being single (APR 1.81, 95% CI: 1.01-3.30). Obese patients had an increased risk (APR 1.48, 95% CI:1.01-2.19) of developing HTN as compared to those with normal Body Mass Index.

Conclusion: High hypertension prevalence was observed among hydrocele patients. The age of ≥ 45 years, obesity, and being married were independently associated with hypertension.

Recommendation: The Ministry of Health (MOH) to establish an integrated program between Non-Communicable Diseases (NCDs) such as HTN in managing patients with lymphatic filariasis hydrocele. MOH to provide health education on HTN screening, obesity combating, and marriage counseling to LF patients.

4. Assess urban versus rural living location associated with the probability of meeting the WHO movement behavior guidelines in LMICs.

Authors: Jackline Jema Nusrupia, Leyna H. Germana, Pujitha Wickramasinghe, Hong K. Tang, Nyaradzai Munambah, Mohammad S. Hossain, Pham Bang, Guan, Hongyan, Alex Antonio Florindo, Catherine E. Draper, Denise Koh, Adang Suherman, Anthony D. Okely, Mark S. Tremblay, Xanne Janssen, John J. Reilly.

Affiliation: Tanzania Food and Nutrition Centre (TFNC).

Background: Insufficient physical activity, excessive screen time, and short sleep duration may be common globally among young children in low- and middle-income countries (LMICs). However, data on prevalence of meeting World Health Organization 24-hour movement behaviour guidelines among 3–4-year-olds in LMICs are limited, and it is unknown whether urbanization is related to young children's movement behaviors.

Objective: To examine the proportion of 3–4-year-old children from LMICs meeting the WHO Guidelines and to assess whether urban versus rural living location is associated with the probability of meeting the WHO movement behavior guidelines in LMICs.

Methodology: The SUNRISE Study recruited 429, 3–4-year-old child/parent dyads from 10 LMICs. The children wore activPAL accelerometers continuously for at least 48 hours to assess their physical activity and sleep duration. Screen time and time spent restrained were assessed via parent questionnaire. Differences in the prevalence of meeting guidelines between urban and rural dwelling children were examined using chi-square tests.

Results: Physical activity guidelines were met by 17% of children (14% urban vs 18% rural), sleep guidelines by 57% (61% urban vs 54% rural), screen time guidelines by 50% (50% urban vs 50% rural), restrained guidelines by 84% (81% urban vs 86 % rural), and all guidelines combined by 4% (4% urban vs 4% rural). We found no significant differences in meeting the guidelines between urban and rural areas.

Conclusion: Only a small proportion of children in both rural and urban settings met the combined movement guidelines. Strategies to improve movement behaviors in LMICs should be considered including both rural and urban settings.

Recommendation: It is therefore critical to include rural and urban settings in future public health surveillance of the movement behaviors, and in mitigation strategies for physical inactivity epidemics in LMICs.

5. Assessment of factors associated with the use of *Securidaca longipedunculata* powder "Mkongo" as an aphrodisiac among male adults in Kinondoni district in Dar Es salaam.

Authors: Bryceson Mkinga, Allan Kiiza Lwambura, Rogers Mwakalukwa, Doreen Mloka, Cleopatra Justine Shonyella, Judith Costantine.

Affiliation: Muhimbili University of Health and Allied Sciences (MUHAS).

Background: *Securidaca longipedunculata* plant has long history in African traditional medicine. The stem powder, famously called "Mkongo" used as an aphrodisiac in males is not registered in Tanzania. its use among adults in Tanzania raises an important public health concern. Necessitating a need to determine factors influencing its use in Tanzania.

Objective: To assess factors associated with the use of *S. longipedunculata* powder "Mkongo" as male aphrodisiac.

Methodology: This was a qualitative cross-sectional study conducted between January and March 2023, among males in Kinondoni district, Dar Es Salaam. Participants were purposefully selected. The data was collected using focus group discussions. Discussions were audiotaped, transcribed verbatim and analyzed using thematic analysis.

Results: Eight (8) themes emerged which are awareness on *S. longipedunculata* powder "Mkongo", perception towards sexual dysfunction and perception towards traditional medicine, experience of using Mkongo as an aphrodisiac, factors associated with the use of mkongo, mixed

social cultural use of *S. longipedunculata* powder "Mkongo", limitations and impacts associated with the use of *S. longipedunculata* powder "Mkongo" and recommended interventions.

Conclusion: Our study has revealed factors associated with the use of *S. longipedunculata* powder "Mkongo"

Recommendation: Evidence-based research and regulation is essential to ensure the safety of consumers in herbal medicines.

6. An international study of 24-hour movement behaviors during the early years (SUNRISE): a pilot study from Tanzania.

Author: Jackline J. Nukurupia, Leyna H. Germana, Hoyce Mshida, Adeline Munuo, Xanne Janssen, John J. Reilly.

Affiliation: Tanzania Food and Nutrition Centre, Strathclyde University.

Background: As seen from the perspective of movement, the 24-hour period is divided between sleep, sedentary behaviors, and physical activity (the 24-hour 'movement behaviors'). Time spent in physical activity, sedentary behaviors, and sleep in children influences obesity and many other health indicators (Okely 2018).

Objective: The objectives of this study were to (i) to assess the feasibility of the methods to be used in SUNRISE main study (ii) to determine the proportion of Tanzanian 3- and 4-year-olds who meet the WHO guidelines for physical activity, sedentary behaviors, and sleep.

Methodology: The SUNRISE Study recruited 110, 3–4-year-old child/parent dyads from Ilala urban/rural. The children wore actiGraph accelerometers continuously for at least 48 hours to assess their physical activity and sleep duration. Screen time and time spent restrained were assessed via parent questionnaire. Differences in the prevalence of meeting guidelines between urban and rural dwelling children were examined using chi-square tests.

Results: There were no significant differences in time spent in movement behaviors between the genders. However, the resident area of a child showed significant differences in some of the movement behaviors. Sleeping- Children from rural settings spent a significantly higher amount of time sleeping 702 (95%CI 674.3, 728.9) than their counterparts. Restrained -Children from urban settings spent a significantly higher amount of time restrained 42 (95%CI 34.6, 48.8) than their counterparts. TPA Children from rural settings spent a significantly higher amount of time on

PA 239 (95% 221.7, 256.1) than their counterparts. LPA Children from rural settings spent a significantly higher amount of time on LPA 130 (95% 121.3, 139.1) than their counterparts.

Conclusion: Only a small proportion of children in both rural and urban settings met the combined movement guidelines. Strategies to improve movement behaviors in LMICs should consider including both rural and urban settings.

Recommendation: Tanzania needs to adopt/adapt these guidelines to our own context.

POSTER PRESENTATION

1. International study of 24-hour movement behaviors during the early years (SUNRISE): a pilot study from Tanzania.

Subtheme: Role of urbanisation, migration, climate change and pollution in NCDs.

Authors: Jackline Jema Nukurupia, Leyna H. Germana, Pujitha Wickramasinghe, Hong K. Tang, Nyaradzai Munambah, Mohammad S. Hossain, Pham Bang, Guan, Hongyan, Alex Antonio Florindo, Catherine E. Draper, Denise Koh, Adang Suherman, Anthony D. Okely, Mark S. Tremblay, Xanne Janssen, John J. Reilly.

Affiliation: Tanzania Food and Nutrition Centre.

Background: Insufficient physical activity, excessive screen time, and short sleep duration may be common globally among young children in low- and middle-income countries (LMICs). However, data on prevalence of meeting World Health Organization 24-hour movement behavior guidelines among 3–4-year-olds in LMICs are limited, and it is unknown whether urbanization is related to young children's movement behaviors.

Objective: To examine the proportion of 3–4-year-old children from LMICs meeting the WHO Guidelines and to assess whether urban versus rural living location is associated with the probability of meeting the WHO movement behavior guidelines in LMICs.

Methodology: The SUNRISE Study recruited 429, 3–4-year-old child/parent dyads from 10 LMICs. The children wore activPAL accelerometers continuously for at least 48 hours to assess their physical activity and sleep duration. Screen time and time spent restrained were assessed via parent questionnaire. Differences in the prevalence of meeting guidelines between urban and rural dwelling children were examined using chi-square tests.

Results: Physical activity guidelines were met by 17% of children (14% urban vs 18% rural), sleep guidelines by 57% (61% urban vs 54% rural), screen time guidelines by 50% (50% urban vs 50% rural), restrained guidelines by 84% (81% urban vs 86 % rural), and all guidelines combined by 4% (4% urban vs 4% rural). We found no significant differences in meeting the guidelines between urban and rural areas.

Conclusion: Only a small proportion of children in both rural and urban settings met the combined movement guidelines. Strategies to improve movement behaviors in LMICs should consider including both rural and urban settings.

Recommendation: It is therefore critical to include rural and urban settings in future public health surveillance of the movement behaviors, and in mitigation strategies for physical inactivity epidemics in LMICs.

2. Dietary and socio-demographic factors associated with being overweight and obese among primary school adolescents in mainland Tanzania: Evidence from the 2021 SMNS cross-sectional school-based survey.

Subtheme: Nutrition and NCDs

Authors: Nyamizi Julius, Adeline Munuo, Rose Msaky, Elizabeth John, Eliasaph Mwana, Abela Twinomujuni, Dorice Katana, Juliet Itatiro.

Affiliation: Tanzania Food and Nutrition Centre (TFNC).

Background: Obesity and overweight among children and adolescents have become a growing global public health concern, including in mainland Tanzania. Understanding the dietary and socio-demographic factors associated with overweight and obesity in primary school adolescents is crucial for developing effective preventive strategies and interventions.

Objective: To determine the dietary and socio-demographic factors associated with the prevalence of overweight and obese among primary school adolescents in mainland Tanzania.

Methodology: "This study is a secondary data analysis of the School Malaria and Nutrition Survey conducted in 2021 by the Ministry of Health through the National Malaria Control Program and Nutrition Services in collaboration with the President's Office Regional Administration and Local Government. A multi-stage cluster sampling was used to select a representative school and ultimately School Age Children and households for the survey. Random selection of SAC from the selected schools and a random selection of 10% SAC for household visits. Children were selected systematically by using the school register and a 1:1 ratio for girls and boys from standards 1 through 6 was applied. Based on a proportional allocation to the primary school population size using a master pupil list from PO-RALG, each school was assigned a specific number of children to be sampled ranging from a minimum of 60 to a maximum of 120. The study population were SAC (5-9 years of age) and adolescents (10- 16 years of age) from public primary schools and households in mainland Tanzania. All enrolled pupils aged between 5 and 16 years who were present during the day of the survey were eligible to participate. Heads of households or representative members of selected households nearby the sampled schools were also eligible to participate. The study excluded SAC who were not present at school or sick during the survey day. The sample size was estimated at council level based on council malaria prevalence

Appendix 0: THE 3RD NATIONAL NCDs SCIENTIFIC CONFERENCE



THE MINISTRY OF HEALTH, COMMUNITY DEVELOPMENT, GENDER, ELDERLY AND CHILDREN (MOHCDGEC), THROUGH THE TANZANIA NCDs PREVENTION AND CONTROL PROGRAMME IN COLLABORATION WITH MUHIMBILI UNIVERSITY OF HEALTH AND ALLIED SCIENCES (MUHAS)



The Ministry of Health, Community Development,
Gender, Elderly and Children
in collaboration with
Muhimbili University of Health and Allied
Sciences



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9 789912 401365

3rd National NCDs Conference at Arusha International Conference Centre, 11th – 12th November, 2021



4. Practices and Predictors of Diabetes Mellitus Screening among adults in Kilimanjaro region, Tanzania

Author: Juliana B. Panga, Mariam J Munyogwa

Institution: University of Dodoma, School of Nursing and Public Health

Background: There is a growing burden of non-communicable diseases in low- and middle-income countries (LMICs), in particular those of the sub-Saharan African countries. While there is an emphasis on primary prevention through promotion of healthy diet, physical activity, and reduction of smoking, diabetes mellitus (DM) screening is also crucial for prevention and early management of the disease. However, information is still scarce on the screening practices of DM and associated factors in Northern Tanzania.

Aim: To determine the screening practices of diabetes mellitus and the associated predictors among adults in the Kilimanjaro Region, Tanzania.

Methodology: The cross-sectional study was carried out between February and April 2021. A face-to-face interview using a standardized questionnaire was conducted. Collected information included sociodemographic characteristics of the participants, diabetes mellitus screening practice, and the factors influencing DM screening. Analysis was done using descriptive statistics and a multivariate logistic regression model.

Results: A total of 420 eligible participants were involved in this study. The proportion of ever screened for diabetes stood at 28.8%. Significant predictors for DM screening included elderly age [AOR=2.03; 95%CI: 1.19-3.47; p=0.009]; secondary education and above [AOR=5.45; 95%CI: (2.65-11.23), p<0.001] and [AOR=2.85; 95%CI: (1.06-7.62), p=0.037]; formally employed [AOR=1.87; 95%CI: (1.01-7.62), p=0.048]; family history of DM [AOR=3.93; 95%CI: (2.00-7.74), p<0.001]; and accessibility of facilities for DM screening services [AOR=2.66; 95%CI: (1.41-5.00), p=0.002].

Conclusion: The proportion of ever being screened for diabetes was low. Elderly age, higher education, and availability of DM screening services significantly predicted DM screening.

Recommendations: Public health efforts need to focus on awareness creation for DM screening through a systematic Diabetes screening program specifically in primary health care settings.

5. The extent to which levels of habitual physical activity, sedentary behaviour and sleep complied with WHO Guidelines in 3–4-year-old children in Sub-Saharan Africa

Main author: Jackline Nusrupia, John Reilly and Xanne Janssen

Affiliated Institutions: Tanzania Food and Nutrition Centre and Strathclyde University



Background; Physical inactivity has been identified as a leading factor for global mortality and a contributor to the global rise in overweight and obesity. The number of overweight or obese infants and young children (age 0 to 5 years) increased from 32 million globally in 1990 to 40 million in 2016 and it has been projected to reach 50 million by 2030 [WHO 2018]. In a global effort to counter the rise in overweight and obesity the World Health Organization developed 24-hour movement behaviors guidelines for the early years (comprising physical activity, sedentary behavior, and sleep).

Aim: To quantify the extent to which levels of habitual physical activity, sedentary behavior and sleep complied with WHO Guidelines in 3-4-year-old children in Sub-Saharan Africa.

Methodology: The systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A literature search was conducted in August 2019 searching PubMed, Web of Science, and Medline Ovid databases as well as grey literature. Eligible studies were assessed for their quality by using the Joanna Briggs Institute (JBI) tool for prevalence studies and findings were summarized.

Results: Four studies were eligible and included in this systematic review, three from South Africa and one from Ghana, in a total of 640 participant. Three studies showed high compliance with the physical activity guidelines, one showed high compliance with the screen time guidelines, and none reported on sleep. Few studies have examined the levels of or compliance with 24-hour movement behaviors in pre-school children in Sub-Saharan Africa to date

Conclusion; This review highlighted insufficient data to make definitive conclusions on adherence to the 24-hour movement recommendations in Sub-Saharan Africa.

Recommendation; Future research on levels of the 24-hour movement behaviors among young children in Sub-Saharan Africa should be conducted.

6. Factors influencing preventive measures against hypertension among relatives escorting patients at cardiac institute in Tanzania

Author: Baraka K. Karim, Saidi Kilindimo

Institution: Muhimbili University of Health and Allied Sciences

Background: Hypertension is a risk factor for cardiovascular morbidity and mortality. Appropriate lifestyle modifications are a fundamental step in the prevention of hypertension, which is the strongest risk factor for cardiovascular disease. In Africa, hypertensive heart disease has a prevalence of 46% for adults aged 25 and above. Management of hypertensive heart diseases involves education on the disease, its interrelations and complications, use of medications, and mostly lifestyle modification.