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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

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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 approved 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 century[3]; 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 behaviour[3] and sleep duration[7] 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 paradigm[9] 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 Canada[10] 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 multicountry 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 review[4] 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 development 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 Behavioral 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 Tladi
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	Amonje Moses Oluchiri
Malawi	AFRO	Low-income	Centre for Social Research, University of Malawi	Zomba, Malawi	Urban: Lilongwe, Central Malawi Rural: Karonga, Northern Malawi	Tawonga Mwase-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	Germana Leyna Jackline Nusurupia
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	Fazlollah Ghofranipour
Morocco	EMRO	Lower-middle income	Unite Mixte de Recherche en Nutrition et Alimentation	Rabat, Morocco	Urban: Rabat-Salé-kénitra Region Rural: Rabat-Salé-kénitra Region	Asmaa El Hamdouchi
Pakistan	EMRO	Lower-middle income	Precision Health Consultants Global	Karachi, Pakistan	Urban: Karachi West and Central Districts Rural: Larkana, Sindh, Pakistan	Ali Turrab 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
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 Kontsevaya
Scotland	EURO	High-income	University of Strathclyde	Glasgow, Scotland	Urban: Greater Glasgow Rural: Dumfries and Galloway, Argyll and Bute	John Reilly Xanne Janssen

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
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: Itabiba municipality	Alex Antonio Florindo
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. Staiano E.Kipling Webster
Bangladesh	SEARO	Lower-middle income	Biomedical Research Foundation	Dhaka, Bangladesh	Urban: Dhaka district Rural: Dhaka district	Mohammad Sorowar 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
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	Naknon Pathom, Thailand	Urban: Bangkok region Rural: Central region	Piyawat Katewongsa Dyah Anantalia Widyastari
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: Shijinshan district (Beijing) Rural: Huairou district and Fangashan 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

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
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	Ulaanbaater, 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
Vietnam	WPRO	Lower-middle income	Pham Ngoc Thach University of Medicine	Ho Chi Minh City, Vietnam	Urban: District Tân Bình and District 1, Ho Chi Minh city Rural: District Bình Chánh and District Nhà Bè, Ho Chi Minh city	Hong Kim Tang Thanh Van Kim

*Obtained from the World Bank. Data—World Bank Country Lending Groups, 2020.
AFRO, African region; EMRO, Eastern Mediterranean region; EURO, European region; PAHO, Pan-American 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 parents[25] 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.

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 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).

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.

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 accelerometry[27] (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 behaviour[28] 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-intensity to vigorous-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:

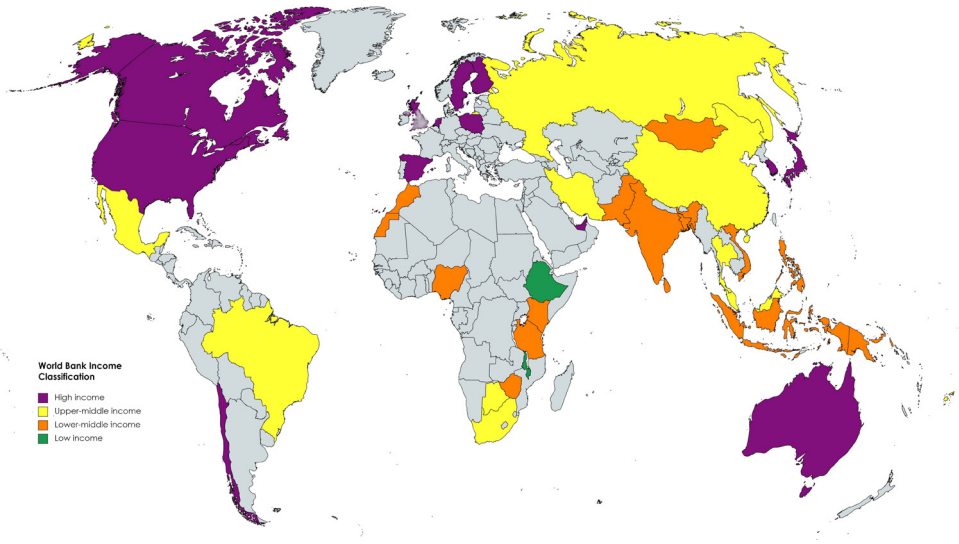

Figure 1 Map of participating countries.

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.
- 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 locomotion), respectively. This recommendation was made

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		
AustraliaBangladesh 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

Table 3 Continued

Countries	Measures	Reasons for modification of protocol
Botswana Ethiopia India Indonesia Iran Malawi Mexico Nigeria Netherlands Pakistan Russia Singapore Thailand Finland UAE Chile Fiji Tanzania Mongolia Philippines	Child ► Movement behaviours—ActiGraph. ► Anthropometry—height and weight. ► Executive Function Tests—Mr Ant, Go/NoGo. ► Motor skills (NIH Toolbox). Parent ► Parent/caregiver questionnaire. ► Food habits and eating behaviour questions added to survey. Centre staff ► Focus groups. ► Questionnaire.	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. Elements from the non-proprietary NIH Toolbox were deemed more culturally feasible and will replace the ASQ to assess motor skills. Food habits and eating behaviour questions added to parent/caregiver questionnaire to provide additional context for interpreting anthropometric data. Centre questions added to gain more insight into the influences on movement behaviours in the child care centre setting.

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

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 insecurity[37] at the family level. Further, sociodemographic information based on a modified version of the WHO STEPS survey[38] 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 (PM2.5), PM10 levels and give and 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

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 Ant) (%)	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	91.2	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 activPAL was pilot tested in these countries.
‡Data collected at the village level.
ECEC, Early Childhood Education and Care; EYT, Early Years Toolbox.

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 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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Correction notice This article has been corrected since it first published. Author name 'Anthony D Okely' has been updated.

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REFERENCES

1 Carson V, Lee EY, Hewitt L. Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). *BMC Public Health* 2017;17:33–63.
2 Lea AJ, Tung J, Archie EA, *et al*. Bridging research in evolution and human health. *Evol Med Public Heal* 2017;2017:162–75.
3 Poitras VJ, Gray CE, Janssen X, *et al*. Systematic review of the relationships between sedentary behaviour and health indicators in the early years (0–4 years). *BMC Public Health* 2017;17.
4 Rollo S, Antsygina O, Tremblay MS. The whole day matters: understanding 24-hour movement guideline adherence and relationships with health indicators across the lifespan. *J Sport Health Sci* 2020;9:493–510.
5 UNICEF. *The State of the World's children 2019. Children,* food and nutrition: growing well in a changing World 2019.
6 Voce A. Cities alive: designing for urban Childhoods. *Child Youth Environ* 2018;28:78.
7 Chaput J-P, Gray CE, Poitras VJ, *et al*. Systematic review of the relationships between sleep duration and health indicators in the early years (0–4 years). *BMC Public Health* 2017;17.
8 World Health Organization [WHO]. WHO guidelines on physical activity, sedentary behaviour for children under 5 years of age, 2019. Available: http://www.who.int/iris/handle/10665/311664
9 Tremblay MS. Introducing 24-hour movement guidelines for the early years: a new paradigm gaining momentum. *J Phys Act Health* 2020;17:92–5.
10 Tremblay MS, Carson V, Chaput J-P, *et al*. Canadian 24-hour movement guidelines for children and youth: an integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab* 2016;41:S311–27.
11 Okely AD, Ghersi D, Hesketh KD, *et al*. A collaborative approach to adopting/adapting guidelines - The Australian 24-Hour Movement Guidelines for the early years (Birth to 5 years): an integration of physical activity, sedentary behavior, and sleep. *BMC Public Health* 2017;17:869.
12 Monasta L, Batty GD, Cattaneo A, *et al*. Early-Life determinants of overweight and obesity: a review of systematic reviews. *Obes Rev* 2010;11:695–708.
13 NCD Risk Factor Collaboration (NCD-RisC). Height and body-mass index trajectories of school-aged children and adolescents from 1985 to 2019 in 200 countries and territories: a pooled analysis of 2181 population-based studies with 65 million participants. *Lancet* 2020;396:1511–24.
14 UNICEF. The State of the World's Children 2017. Children in a Digital World 2017.
15 Brockmann PE, Diaz B, Damiani F, *et al*. Impact of television on the quality of sleep in preschool children. *Sleep Med* 2016;20:140–4.
16 Clark H, Coll-Seck AM, Banerjee A, *et al*. A future for the world's children? A WHO–UNICEF–Lancet Commission. *The Lancet* 2020;395:605–58.
17 de Lucena Martins CM, Lemos LFGBP, de Souza Filho AN, *et al*. Adherence to 24-hour movement guidelines in low-income Brazilian preschoolers and associations with demographic correlates. *Am J Hum Biol* 2021;33:1–12.
18 Guan H, Zhang Z, Wang B, *et al*. Proportion of kindergarten children meeting the who guidelines on physical activity, sedentary behaviour and sleep and associations with adiposity in urban Beijing. *BMC Pediatr* 2020;20:1–9.

19 Okely AD, Veldman SL, de Rosnay M. Relationships between motor skill delay and executive functions in vulnerable children aged 3-5 years. *North Am Soc Study Psychol Sport Phys Act* 2017;39:S34.
20 Wei QW, Zhang JX, Scherpbier RW, *et al*. High prevalence of developmental delay among children under three years of age in poverty-stricken areas of China. *Public Health* 2015;129:1610–7.
21 Veldman SL, Jones RA, Okely A. Prevalence and risk factors of gross motor delay in Pre-schoolers from low-income communities. *J Pediatr* 2020;56:571–6.
22 Bello AI, Quartey JNA, Appiah LA. Screening for developmental delay among children attending a rural community welfare clinic in Ghana. *BMC Pediatr* 2013;13:119.
23 Bronfenbrenner U. *Readings on the development of children. In: ecological models of human development*. New York: Freeman, 1993: 37–43.
24 United Nations - Department of Economic and Social Affairs Population Division. World urbanization prospects 2014.
25 Katzmarzyk PT, Barreira TV, Broyles ST, *et al*. The International study of childhood obesity, lifestyle and the environment (ISCOLE): design and methods. *BMC Public Health* 2013;13:900.
26 Teo K, Chow CK, Vaz M, *et al*. The prospective urban rural epidemiology (pure) study: examining the impact of societal influences on chronic noncommunicable diseases in low-, middle-, and high-income countries. *Am Heart J* 2009;158:1–7.
27 Taylor RW, Haszard JJ, Meredith-Jones KA, *et al*. 24-H movement behaviors from infancy to preschool: cross-sectional and longitudinal relationships with body composition and bone health. *Int J Behav Nutr Phys Act* 2018;15:1–14.
28 Janssen X, Cliff DP, Reilly JJ, *et al*. Predictive validity and classification accuracy of ActiGraph energy expenditure equations and cut-points in young children. *PLoS One* 2013;8:e79124.
29 Smith C, Galland B, Taylor R, *et al*. ActiGraph GT3X+ and Actical wrist and hip worn Accelerometers for sleep and wake indices in young children using an automated algorithm: validation with polysomnography. *Front Psychiatry* 2019;10:1–12.
30 World Health Organization [WHO]. Training course on child growth assessment 2008.
31 Reuben DB, Magasi S, McCreath HE, *et al*. Motor assessment using the NIH Toolbox. *Neurology* 2013;80:S65–75. 11.
32 Clark JE, Damiano DL, Newell KM. Justification for and proposed assessment of motor function. For the National Children's study. *Unpubl Work Prod Doc* 2014.
33 Ulrich D. *Test of gross motor development 2: examiner's manual*. 2nd ed. Austin, TX: PRO-ED, 2000.
34 Ulrich D. *The test of gross motor development –Third Edition (TGMD-3)*. 3rd ed. Austin, TX: PRO-ED, 2019.
35 Howard SJ, Melhuish E. An early years toolbox for assessing early executive function, language, self-regulation, and social development: validity, reliability, and preliminary norms. *J Psychoeduc Assess* 2017;35:255–75.
36 UNICEF & WHO. Indicators for assessing infant and young child feeding practices. World Heal Organ; WHA55 A55/:19, 2008. Available: http://apps.who.int/iris/bitstream/handle/10665/44306/9789241599290_eng.pdf?sequence=1%0Ahttp://whqlibdoc.who.int/publications/2008/9789241596664_eng.pdf%5Cnhttp://www.unicef.org/programme/breastfeeding/innocenti.htm%5Cnhttp://innocenti15.net/declaration
37 Coates J, Swindale A, Bilinsky P. HFIAS for measurement of food access indicator guide. *J Chem Inf Model* 2013;53:1689–99.
38 World Health Organisation. The who stepwise approach to non-communicable disease risk factor surveillance (steps), 2011. Available: http://www.searo.who.int/entity/noncommunicable_diseases/data/mmr_2009_steps_survey_report.pdf
39 Harris PA, Taylor R, Minor BL, *et al*. The REDCap Consortium: building an international community of software platform partners. *J Biomed Inform* 2019;95:103208.
40 Harris PA, Taylor R, Thielke R, *et al*. Research electronic data capture (REDCap)--a metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform* 2009;42:377–81.
41 Cohen J. *Statistical power analysis for the behavioral sciences*. 2nd Ed. New York: Lawrence Erlbaum, 1988.
42 Cliff DP, McNeill J, Vella SA, *et al*. Adherence to 24-hour movement guidelines for the early years and associations with social-cognitive development among Australian preschool children. *BMC Public Health* 2017;17:857.
43 Brakenridge CL, Fjeldsoe BS, Young DC, *et al*. Evaluating the effectiveness of organisational-level strategies with or without an activity tracker to reduce office workers' sitting time: a cluster-randomised trial. *Int J Behav Nutr Phys Act* 2016;13:115.
44 Headley S, Hutchinson J, Wooley S, *et al*. Subjective and objective assessment of sedentary behavior among College employees. *BMC Public Health* 2018;18:768.