WILEY

RESEARCH ARTICLE OPEN ACCESS

Associations Between 24-h Movement Behaviours and Health in 3- and 4-Year-Old Children From a Low-Income Country: The SUNRISE Ethiopia Study

Chalchisa Abdeta[1] | Dylan Cliff[1] | Katharina Kariippanon[2] | Alem Deksisa[3] | Sileshi Garoma[3] | Debrework Tesfaye[4] | Anthony D. Okely[2]

[1]Early Start, School of Education, University of Wollongong, Wollongong, Australia | [2]Early Start, School of Health and Society, University of Wollongong, Wollongong, Australia | [3]Department of Public Health, Adama Hospital Medical College, Adama, Ethiopia | [4]Department of Sport Sciences, Wolaita Sodo University, Wolaita, Ethiopia

Correspondence: Chalchisa Abdeta (cat179@uowmail.edu.au)

Received: 9 July 2024 | **Revised:** 12 April 2025 | **Accepted:** 14 May 2025

Funding: This work was supported by the University of Wollongong, Australia.

Keywords: adiposity | childhood development | executive functions | motor skills

ABSTRACT

Background: There is little evidence on the associations between 24-h movement behaviours and health in children from low-income countries. We examined the associations of physical activity, sedentary behaviour, screen time and sleep with adiposity, motor skills and executive functions among 3- and 4-year-old children in Ethiopia.

Methods: Cross-sectional study conducted in Adama city and Lume Woreda, Oromia region, Ethiopia. We recruited children from kindergartens and rural Kebeles or villages. Children's time spent in physical activity, sedentary behaviour and sleep were measured using hip worn ActiGraph accelerometers. Children's screen time was parent-reported. Linear mixed models tested associations of 24-h movement behaviours with adiposity (BMI *z*-score), motor skills (NIH Toolbox) and executive functions (Early Years Toolbox). All models accounted for child sex, age and dietary diversity as fixed effects and clustering of children within kindergarten/villages as a random effect.

Results: A total of 430 children participated (4.2 ± 0.6 years). Children who slept longer had lower adiposity (−0.12, 95% CI: −0.19, −0.06). Those who had higher levels of total physical activity (TPA) (0.06, 95% CI 0.01, 0.13) and moderate to vigorous-intensity physical activity (MVPA) (0.03, 95% CI 0.01, 0.06) had higher scores on handgrip strength. Children who spent more time in sedentary behaviour had lower handgrip strength (−0.08, 95% CI −0.16, −0.01). There were no significant associations with executive functions.

Conclusions: Strategies to improve adiposity and motor skills should focus on promoting healthy levels of 24-h movement behaviours, especially adequate sleep and time spent in physical activity in Ethiopian children.

Abbreviations: BMI, body mass index; HICs, high-income countries; LICs, low-income countries; MVPA, moderate to vigorous-intensity physical activity; REDCap, Research Electronic Data Capture; STROBE, Strengthening the Reporting of Observational Studies in Epidemiology; TPA, total physical activity; WHO, World Health Organisation.

Summary

- Longer sleep helps reduce body fat in young children.
- More physical activity and less sedentary time boost motor skills, specifically handgrip strength.
- No significant association was found between movement behaviours and executive functions.
- Promoting good sleep and physical activity is crucial for the health and development of Ethiopian children.

1 | Background

Healthy levels of physical activity, sleep and sedentary behaviour, referred to as 24-h movement behaviours, provide a foundation for healthy growth and development in the early years (Chaput et al. 2014; Kuzik et al. 2017; World Health Organisation 2018; Tremblay 2020). The World Health Organisation (WHO) has published guidelines on these behaviours for children under 5 years of age, providing recommendations to optimise health and development (World Health Organisation 2019). These guidelines recommend that, for children aged 3 to 4 years, a 24-h period should comprise (i) at least 180 min of total physical activity (TPA), of which at least 60 min should be moderate to vigorous in intensity (MVPA); (ii) less than 60 min of sedentary screen time and not being restrained for more than an hour at a time and (iii) 10–13 h of good quality sleep (World Health Organisation 2019).

These guidelines were developed based on evidence of associations between 24-h movement behaviours and health (World Health Organisation 2018). However, nearly all the evidence was obtained from high-income countries (HICs) (World Health Organisation 2018), which represent only 10% of children globally (United Nations International Children's Emergency Fund 2024). Associations between movement behaviours and health might be different among children in low-income countries (LICs) due to socio-economic inequalities, lifestyles and environmental factors (Rollo et al. 2020). A recent review found very few studies on associations between 24-h movement behaviours and health among children in Sub-Saharan Africa, where most LICs are located (Nusurupia et al. 2020). The aim of this study was to examine the associations of time spent in physical activity, sedentary behaviour and sleep with selected health outcomes among 3- and 4-year-old children living in a low-income country, Ethiopia.

2 | Methods

2.1 | Study Design and Setting

This cross-sectional study was reported using the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (von Elm et al. 2007). Our study was conducted in Ethiopia, the second most populous country in Africa with more than 120 million people including 18 million children under the age of five (United Nations International Children's Emergency Fund 2024), as a part of the SUNRISE international study (Okely et al. 2021). We sampled children from the Oromia region, one of the largest regions in the country, specifically in Adama city and Lume Woreda. Adama is a major city located about 100 km (km) South-East of Addis Ababa, the capital city, with a population of approximately 500 000. Currently, the town has 120 kindergartens, all of which are privately owned. Lume Woreda has 35 rural kebeles, the lowest administration structure in the country, which located in the East Shewa Zone approximately 50 km from Adama. No kindergartens exist in rural Ethiopia. Children were recruited from kindergartens in Adama and from rural kebeles or villages in Lume Woreda. Data were collected between 01 April 2022 and 30 September 2022, which was during the COVID-19 pandemic, but the country remained unaffected and all activities continued as usual way.

2.2 | Study Participants

We invited preschool children aged 3.0–4.9 years, who were free from any health conditions or disabilities. We used a combination of random and convenience sampling to recruit eligible children. Convenience sampling was used to select 18 kindergartens in Adama city and 11 rural kebeles in Lume Woreda. In the urban area, directors of selected kindergartens received prior information about the selection process to identify eligible children from a range of socio-economic backgrounds within their kindergartens. Data collectors ensured that the list of selected children included an equal number of boys and girls from each kindergarten. Parents of eligible children were invited to participate through interactions with the data collectors who visited kindergartens. A brief explanation of the study was given to parents when they dropped off/picked up their children. A maximum of 20 children were recruited from each kindergarten based on the SUNRISE international study protocol (Okely et al. 2021). In cases where the directors provided more than 20 eligible children, 20 children (10 boys/10 girls) were randomly selected using a lottery method. In rural areas, community health extension workers were provided list of eligible children from their health registry in each selected kebele. Data collectors approached and invited parents to participate in the study. A maximum of 20 children were recruited from each kebele based on the SUNRISE study protocol (Okely et al. 2021). In cases where the community health extension workers provided more than 20 eligible children, 20 children (10 boys/10 girls) were randomly selected using a lottery method.

2.3 | Measurements

2.3.1 | Physical Activity, Sedentary and Sleep Time

Physical activity, sedentary and sleep time were measured using the triaxial ActiGraph wGT3X-BT accelerometer (ActiGraph 2022), which was validated for this age group (Okely et al. 2021; Janssen et al. 2013). The monitors were initialised using the ActiLife software (version 6.12.1) (ActiGraph 2019) before being placed on children. Eligible children were asked to continuously wear the monitor under their clothes on the right hip using an elastic belt for five consecutive days and nights. The children and their families removed the monitors during water-based activities and were asked to refit the monitors immediately afterwards. In the urban area, data collectors made daily follow-ups to check activity monitoring and compliance, while community health workers did the same in the rural setting. Every morning, the data collectors/community health workers ensured that the belt was fastened on the child's waist and that the monitor was positioned over the right hip with the button facing upwards. The monitors recorded data at a 30-Hz sampling rate. Monitor data were downloaded using the ActiLife software (ActiGraph 2019).

2.4 | Accelerometer Data Reduction and Processing

Accelerometer data were processed using the 'PhysicalActivity' package (version 0.2–4) (Choi et al. 2011) in the R software (version 4.2.2) for windows (Team RC 2022). The Actigraph 'gt3x' files were imported into R and collapsed to 15-s epochs for physical activity and converted to counts and saved in readable 'csv' format. Initially, the package used the 'wearingMarking' function to differentiate accelerometer wear and non-wear time. Additionally, the package uses the 'markPAI' function to label physical activity intensity (light, moderate and vigorous) using cut-points developed specifically for preschool children (Choi et al. 2022). Cut points of 800–1679, 1680–3367 and > 3368 counts per minute were applied to classify time spent in light-, moderate- and vigorous-intensity physical activity, respectively (Janssen et al. 2013; Pate et al. 2006; Pate et al. 2015). Afterwards, the 'PhysActBedRest' package (version 1.1) was used in 60-s epochs to identify sleep periods using a decision tree algorithm (Tracy et al. 2014). Data were exported as 'csv' files for non-wear, physical activity, sedentary time, sleep and naps (Tracy et al. 2021).

2.5 | Screen Duration

Sedentary screen time was assessed using the SUNRISE parent questionnaire (Okely et al. 2021), which was administered through face-to-face interviews. The questionnaire was translated into two local languages (Afan Oromo and Amharic language) by professional translators to suit local conditions and back translated to English to confirm consistency. Data were gathered on how much time the child spent using electronic screen devices (smartphone, tablet, computer, television or video game) during a typical day in the past week while sitting or lying down. Data were collected using the Research Electronic Data Capture (REDCap) Software (Harris et al. 2009; Harris et al. 2019) that was hosted at the University of Wollongong, Australia, with server versions of 12.0.1.1 and 12.4.6 and app versions from 5.19.17 to 5.22.4 for data collection, quality and secure handling.

2.6 | Adiposity

Height and weight were measured using a portable stadiometer and calibrated scales following standardised WHO protocols (Lohman et al. 1988). Children were asked to remove their shoes and extra clothes before the measurement, except for those worn for religious purposes. Weight was measured to the nearest decimal (0.1 kg) using portable digital scales. Height was measured to the nearest 0.1 cm while standing upright (standing erect, shoulder relaxed, arms at side, buttock touches measurement board, legs straight and knee together, feet flat with toes forward) using a portable stadiometer. Height and weight were measured twice and the average used to calculate body mass index (BMI) [BMI = Weight in kg/(Height in cm)^2]. Children's adiposity was determined using BMI for age *z*-score, which calculated based on the WHO child growth standards cut-point reference for sex and age (Group WMGRS 2006).

2.7 | Motor Skills

Children's motor skills were examined using the NIH Toolbox (National Institute of Health 2024), which included the Supine Timed Up and Go (S-TUG) test, one-leg standing balance, standing long jump, hand-grip strength and the nine-hole pegboard test (Reuben et al. 2013). Each child performed the tasks in a separate area free from distractions from parents and other children. Prior to each test, children received instructions and an opportunity to practice. In the S-TUG test, the child was asked to lie on their back with their feet on the line, get up quickly on 'Go', run 3 m, touch the wall and return back to the initial place across the line. Start- and end-times were recorded, and average results were calculated to test the child's mobility. Likewise, the child was requested to stand on one leg and balance for a maximum of 30 s without supporting their legs with their hands, and his test was done on each leg, one after the other. Then, the balance scores of each leg were taken to calculate the average of one-leg standing balance test, which assessed the child's postural ability. For standing long jump, the child was instructed to stand with toes behind a line, jump as far as they could and land on both feet. The distance was measured in centimetres to determine how far the child jumped to measure lower body strength and power.

A hand-grip test was measured using dynamometer to assess the muscular strength, which is a marker of children's physical development and well-being (Sanchez-Delgado et al. 2015). Before each test, the data collectors reset the dynamometer to zero and instructed the child to hold it with one hand without touching their body, standing the upright position. Then, the handgrip was adjusted based on the child's second joint of the forefinger being bent at an angle of 90°, and the child asked to squeeze the grip continuously with a full force for a minimum of 3 s recorded in kilogram (closest to 0.5 kg), with each hand alternatively. The average was calculated from the tests performed on both hands.

The nine-hole peg-board test was assessed the child's fine motor skills and dexterity. The pegboard was placed in front of the child and centred on a flat table. The board's tray was positioned on the hand being tested while the other hand stabilised the board. The child was encouraged to complete the task as quickly as possible, picking up and placing the pegs in the holes one at a time in any order until all nine holes were filled. Then, the child was required to take out all pegs one by one using the same hand. The same process was repeated with the other hand. The left-and right-hand tests were recorded, and average results were calculated (von Elm et al. 2007).

2.8 | Executive Functions

Children's executive functions were assessed using the Early Years Toolbox (EYT) (Early Start, University of Wollongong 2024a), which was translated into two local languages (Afan Oromo and Amharic). The EYT is a readily available battery of iPad-based executive function measures that have been designed and psychometrically tested with preschool children (Howard et al. 2017). Two tasks were used to assess key components of executive functions: (1) visual–spatial working memory ('Mr Ant') and (2) inhibition ('Go/No-Go'). Both tasks are self-contained and are 'game-like' assessments implemented using an electronic tablet. Each measure was designed to be brief (≤ 5 min, including instruction and practice), engaging, and leverage the affordances of technology (e.g. animation, audio and accurate capture of responses and response timings). All instructional and practice trials provided feedback to participants. Each task provided standardised administration and instructions visually and orally, with instructions supplemented by the data collectors. Each child completed the EYT tasks in a quite separate place. To play the visual–spatial working memory, children were asked to observe where a sticker was displayed on the cartoon Ant's body parts before being hidden. Then, the child was tasked to replace a sticker again as displayed, remembering the spatial location of stickers. The child earned one point for each consecutive level of the game in which at least two trials were correct. The total correct trials were then added together to determine visual–spatial working memory. For the Go/No-Go task, the child was asked to catch a fish when they passed on the screen (Go) and to avoid touching the sharks when they passed across the screen (No Go). The Go/No-Go score was calculated by multiplying the accurate trials of 'Go' by 'No-Go'. The child's score was classified based on the performance bands of the preliminary norms (Early Start, University of Wollongong 2024b) that derived from Australian preschool children.

2.9 | Covariates

2.9.1 | Child Sex and Age

Data on child's sex and age were collected through the SUNRISE parent questionnaire (Okely et al. 2021). Parents/caregivers were asked, 'what is the date of birth of the child? (dd/mm/yyyy) and if the child's date of birth was not known, how old is the child in years? (Age in completed year)'.

2.9.2 | Dietary Diversity

Questions about dietary diversity was asked and included in the analyses as a covariate for adiposity. Parents reported their child's dietary diversity by responding to the question: 'Did your child eat any of the following types of food yesterday, during the day or night?'. The food types were categorised as whole grains, legumes, dairy products, fresh foods, eggs, vitamins, fruits and vegetables with detailed examples, which helped parents to answer easily. Children who consumed ≤ 3 and ≥ 4 out of seven were categorised as having a low and high dietary diversity, respectively.

2.10 | Statistical Analysis

Children who wore the monitors at least 10 h during waking periods and at least 8 h of sleep over 24-h period having valid data for at least 2 days were included in the analysis to maintain accuracy and reliability of the data (Rich et al. 2014). Normality was checked for continuous variables using histograms. We computed frequency distribution for categorical variables. Descriptive statistics were computed for children's age, adiposity, motor skills and executive functions. Differences between boys/girls and urban/rural were determined using a *t*-test for normally distributed continuous variables. Equivalent nonparametric test (Mann–Whitney *U* test) was used for variables not normally distributed (skewed). Linear mixed models were performed to examine the association between time spent in 24-h movement behaviours (dependent variables), and adiposity, motor skills and executive functions (independent variables). Except for the adiposity model, which additionally adjusted for dietary diversity, all models accounted for child's sex and age as a fixed effects and clustering of children within kindergarten/villages as a random effect in R (version 4.3.1) (Team RC 2023). Statistical significance was set at $p < 0.05$.

3 | Results

3.1 | Characteristics of the Study Participants

A total of 430 children consented to participate in the study. Of these, 56 children were excluded (19 withdrawal due to parents' misconceptions about the accelerometer linked the device to radioactive materials, 30 did not meet minimum accelerometer wear time criteria and seven had incomplete assessments). The final sample included 374 (87%) children. The mean age of the participants was 4.2 (± 0.6) years. Fifty-two percent of the sample were boys, and 16% of the children were overweight/obese.

Table 1 reports differences between the study participants by sex and urban/rural location. Boys had higher levels of adiposity, fine motor skill and muscular strength but lower levels of balance compared with girls. There were significant differences between urban and rural children for all variables except for balance and inhibition. Rural children had lower adiposity, higher agility and fine motor skill and better visual–spatial working memory than their urban peers.

Table 2 reports the associations between time spent in physical activity, sedentary, screen and sleep and adiposity, motor skills and executive functions. Children who slept longer had lower adiposity levels (−0.12, 95% CI −0.19, −0.06). Those who had higher levels of TPA (0.06, 95% CI 0.01, 0.13) and MVPA (0.03, 95% CI 0.01, 0.06) had higher scores in handgrip strength. In contrast, children who spent more time in sedentary had a lower handgrip strength (−0.08, 95% CI −0.16, −0.01).

TABLE 1 | Differences between the study participants by sex/settings ($n = 374$).

Variables	Mean (standard deviation)						
	Total sample	Boys	Girls	p	Urban	Rural	p
Child age (years)	4.21 (0.58)	4.21 (0.57)	4.22 (0.60)	0.718	4.54 (0.39)	3.93 (0.58)	<0.001*
Height (cm)	97.86 (8.04)	97.81 (7.57)	97.92 (8.54)	0.773	103.15 (6.11)	93.38 (6.65)	<0.001*
Weight (kg)	16.07 (3.27)	16.17 (3.09)	15.97 (3.45)	0.467	18.34 (2.84)	14.15 (2.20)	<0.001*
BMI (kg/m^2)	16.65 (1.59)	16.78 (1.49)	16.51 (1.67)	0.072	17.17 (1.61)	16.20 (1.42)	<0.001*
BMI z-score	0.89 (1.04)	1.02 (0.99)	0.76 (1.07)	0.023*	1.26 (1.02)	0.58 (0.95)	<0.001*
S-TUG test (sec)	5.94 (1.58)	5.98 (1.25)	5.89 (1.33)	0.489	5.44 (1.16)	6.36 (1.25)	<0.001*
Balance (sec)	8.97 (6.05)	8.34 (5.81)	9.66 (6.24)	0.029*	9.45 (6.10)	8.56 (5.99)	0.112
Pegboard test (sec)	41.83 (8.56)	42.68 (8.40)	41.91 (8.66)	0.043*	37.95 (7.31)	45.13 (8.18)	<0.001*
Standing long jump (cm)	54.66 (20.35)	54.47 (20.09)	54.88 (20.67)	0.779	62.14 (19.18)	48.30 (19.15)	<0.001*
Handgrip strength (kg)	5.48 (2.36)	5.74 (2.29)	5.19 (2.41)	0.012*	6.07 (2.37)	4.97 (2.25)	<0.001*
Working memory score	1.55 (0.78)	1.59 (0.80)	1.52 (0.75)	0.464	1.42 (0.73)	1.67 (0.80)	0.006*
Inhibition score	0.51 (0.16)	0.53 (0.15)	0.50 (0.16)	0.082	0.50 (0.17)	0.52 (0.15)	0.256

Abbreviations: BMI, body mass index; cm, centimetre; kg, kilogram; m^2, meter square; S-TUG, Supine Timed Up and Go; Sec, second.
*Significant difference observed at $p < 0.05$.

4 | Discussion

In our study, among children in urban and rural Ethiopia, we found that children who slept longer had lower adiposity. Those who had higher levels of TPA and MVPA had better handgrip strength. Conversely, children who spent more time sedentary had lower handgrip strength. We did not find any significant associations with other motor skills or any executive functions.

Existing evidence on associations between sleep and adiposity remains mixed and exclusively from HICs (Rollo et al. 2020; Chaput et al. 2017; Miller et al. 2021). Our finding can be explained by biological and behavioural mechanisms (Chen et al. 2008; Miller et al. 2015). Our research has provided first known evidence from a low-income country, Ethiopia, and further studies are needed to confirm this finding.

We did not find an association between physical activity and adiposity, which is consistent with existing narrative reviews (Veldman et al. 2021), but inconsistent with a meta-analysis (Wiersma et al. 2020), which found association between adiposity and MVPA. A possible reason could be that in our sample, nearly all children attained high activity levels and adequate sleep, and had a normal BMI. This lack of variability could limit the ability to detect significant associations (Wipfli et al. 2021). We support the hypothesis that detecting adiposity in preschool age might be premature due to their rapid growth and that this becomes more apparent at a later age (Evensen et al. 2016). We did not find an association between sedentary or screen time and adiposity, which is consistent with existing evidence (Wiersma et al. 2020; Poitras et al. 2017). Sedentary or screen time might not have the same impact in Ethiopia where most children were highly active and less reliant on screen devices due to limited electricity and internet connectivity, particularly in rural areas. As evidence remains inconsistent about physical activity (Veldman et al. 2021), sedentary behaviour (Wiersma et al. 2020; Poitras et al. 2017) and adiposity from HICs, further studies warranted to provide better insights from LMICs.

We found that children who spent more time in TPA and MVPA had better handgrip strength, and a negative association between sedentary time and handgrip strength. Evidence from previous studies in HICs has been mixed (Haugland et al. 2023; Fang et al. 2017; Serrano-Gallén et al. 2022). Our results might be explained by contextual factors in Ethiopia, where children spend large amounts of time in unstructured outdoor activities, which involves different traditional games and manipulative tasks, which support children to have higher levels of activity and muscular strength (Cook et al. 2019).

We did not find any association between physical activity, sleep, sedentary or screen time and inhibition or working memory. While some prior studies from HICs have reported mixed results (Amat-Camposo et al. 2024; Meredith-Jones et al. 2019; Willoughby et al. 2018; McNeill et al. 2020; Casale and Desmond 2016; Verswijveren et al. 2020), there are limited data from low-income countries. Our finding was consistent with two studies (Munambah et al. 2021; Byambaa et al. 2024) reported from lower middle income countries. A possible explanation for our finding could be that Ethiopian children may have less opportunity to acquire formal executive functions due to socio-economic factors (Hackman et al. 2015). We recommend that future research consider the cultural validity of the EYT (Early Start, University of Wollongong 2024a) to better align with the cultural context of Ethiopian children. Additionally, detecting significant association might be absent due to nearly all children having very high levels of activity (Wipfli et al. 2021). Unfamiliarity with the gadgets and tasks used in the assessments could negatively impact the results, as Ethiopian children may not have prior exposure to these tools, leading to

TABLE 2 | Associations between time spent in movement behaviours and adiposity, motor skills and executive functions in Ethiopian children ($n = 374$).

	TPA (hour/day)		MVPA (hour/day)		Sedentary time (hour/day)		Screen time (hour/day)		Sleep time (hour/day)	
Variables	**Estimate (95%CI)**	***p***	**Estimate (95%CI)**	***p***	**Estimate (95%CI)**	***p***	**Estimate (95%CI)**	***p***	**Estimate (95%CI)**	***p***
BMI Z-score[a]	0.06 (−0.06, 0.17)	0.338	−0.05 (−0.11, 0.01)	0.085	0.05 (−0.09, 0.21)	0.468	0.01 (−0.12, 0.15)	0.869	**−0.12 (−0.19, −0.06)**	**0.001***
S-TUG test (sec)	−0.02 (−0.12, 0.09)	0.760	−0.02 (−0.07, 0.04)	0.564	0.11 (−0.02, 0.24)	0.087	−0.01 (−0.17, 0.07)	0.398	−0.02 (−0.06, 0.06)	0.946
Balance (sec)	0.01 (−0.02, 0.03)	0.739	0.01 (−0.01, 0.02)	0.391	0.02 (−0.01, 0.05)	0.070	−0.01 (−0.04, 0.01)	0.279	−0.01 (−0.02, 0.01)	0.919
Standing long jump (cm)	−0.01 (−0.02, 0.01)	0.283	0.01 (−0.01, 0.02)	0.286	0.01 (−0.01, 0.02)	0.369	−0.01 (−0.02, 0.01)	0.678	−0.01 (−0.02, 0.01)	0.721
Handgrip strength (kg)	0.06 (0.01, 0.13)	0.045*	0.03 (0.01, 0.06)	0.046*	−0.08 (−0.16, −0.01)	0.039*	−0.01 (−0.09, 0.06)	0.692	−0.01 (−0.06, 0.01)	0.197
Pegboard test (sec)	0.01 (−0.01, 0.03)	0.142	−0.01 (−0.02, 0.01)	0.809	−0.02 (−0.04, 0.01)	0.139	−0.01 (−0.02, 0.02)	0.798	0.01 (−0.01, 0.02)	0.250
Working-memory score	0.03 (−0.12, 0.17)	0.708	0.02 (−0.05, 0.09)	0.579	−0.16 (−0.35, 0.02)	0.082	−0.12 (−0.28, 0.05)	0.170	0.02 (−0.06, 0.11)	0.596
Inhibition score	0.18 (−0.52, 0.89)	0.610	−0.09 (−0.44, 0.27)	0.636	−0.25 (−1.15, 0.64)	0.582	0.59 (−0.23, 1.39)	0.158	0.10 (−0.33, 0.52)	0.655

Abbreviations: BMI, body mass index; CI, confidence interval; kg, kilogram; MVPA, moderate-to-vigorous intensity physical activity; S-TUG, Supine Timed Up and Go; Sec, second; TPA, total physical activity.
[a]Eight underweight samples were excluded from adiposity model. All models accounted for child's sex and age, except for adiposity models, which additionally considered dietary diversity, as a fixed effects and clustering of children within kindergarten/villages as a random effect.
*Statistical significance at $p < 0.05$.

some difficulties in understanding and completing the tasks. Considering this finding, further studies with larger representative samples are recommended.

4.1 | Implications/Recommendation

Our study provides the first known evidence from device-based measures of 24-h movement behaviours in Ethiopian children, adding new insights into the context of low-income countries. We recommend that strategies to promote healthy weight and motor development are needed in this age group. Additionally, we highlight the need of longitudinal studies to gain a deeper understanding of movement behaviours and their relationship with health outcomes, as cross-sectional studies are limited in their ability to infer causality. Given that this initial evidence, further studies might be needed with a larger representative sample for deeper understanding.

4.2 | Strengths and Limitations

Strength of this study is use of accelerometry to measure children's physical activity, sedentary time and sleep duration. This method provides more accurate and reliable data compared with parent-reported measures, and more confidence in the evidence relating to the health benefits associated with 24-h movement behaviours in low-income countries. There are several limitations that need to be considered when interpreting our findings. First, we used convenience sampling to recruit kindergartens and rural kebeles due to the setting for this study. While this approach is practical, it may limit the generalisability of the findings. Future research should consider more robust random sampling procedures. Second, children's screen time relied on parent report, which might be challenging for parents who rely on their shadows than watches to estimate time accurately. Third, we did not perform multiplicity adjustment after weighing the pros and cons (Joo et al. 2016); we applied linear mixed models, which might reduce the random errors. Finally, our study is not able to detect causal relationships due to the nature of cross-sectional study design.

5 | Conclusions

Our study found that adequate sleep was associated with healthier adiposity levels in children. Further, adequate muscular strength through physical activity, particularly outdoor play, is recommended. As such, strategies to support healthy levels of 24-h movement behaviours are needed to support healthy childhood development in low-income countries like Ethiopia.

Author Contributions

CA conceptualised the study, processed and analysed data, interpreted findings and led the writing of the manuscript. ADO and DC conceptualised the study, interpreted results and revised the manuscript. KK, AD, SG and DT interpreted the results and revised the manuscript. All authors have read and approved to the final version of the manuscript.

Acknowledgements

The authors extend their gratitude to the SUNRISE Study Coordinating Centre for research equipment and data management support and Mr. Tadesse Tolera, Dr. Tsedey Shume and S/r Hermela Girma who assisted in collecting quality data. Open access publishing facilitated by University of Wollongong, as part of the Wiley - University of Wollongong agreement via the Council of Australian University Librarians.

Conflict of Interests

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are not publicly available due to privacy or ethical restrict. Please direct inquiries to cat179@uowmail.edu.au.

Ethics Approval and Consent to Participate

Ethics approval was obtained from the University of Wollongong Human Research Ethics Committee, Australia and the Institutional Health Research Ethics Review Committee (IHRERC/2018/044) at Adama Hospital Medical College, Ethiopia (AHMC/SR/31/01/2022). Informed written consent was provided by parents/guardians for their children and themselves before participating in the study.

References

ActiGraph. 2019. *ActiLife Software*. ActiGraph.

ActiGraph. ActiGraph wGT3X-BT. Pensacola, FL, USA: ActiGraph, accessed December 8, 2022, https://actigraphcorp.com/actigraph-wgt3x-bt/.

Amat-Camposo, R., B. Riquelme-Gallego, M. J. Soto-Méndez, and Á. Hernández-Ruiz. 2024. "Relationship Between Diet, Nutritional Aspects and Sleep Quality in a Pediatric Population." *Nutrición Hospitalaria* 41, no. 2: 462–476. https://doi.org/10.20960/nh.04805.

Byambaa, A., O. Dechinjamts, B. Jambaldorj, R. A. Jones, K. H. Chong, and A. D. Okely. 2024. "Prevalence and Health Associations of Meeting the World Health Organization Guidelines for Physical Activity, Sedentary Behavior, and Sleep in Preschool-Aged Children: The SUNRISE Mongolia Pilot and Feasibility Study." *Journal of Physical Activity & Health* 21, no. 3: 283–293. https://doi.org/10.1123/jpah.2023-0511.

Casale, D., and C. Desmond. 2016. "Recovery From Stunting and Cognitive Outcomes in Young Children: Evidence From the South African Birth to Twenty Cohort Study." *Journal of Developmental Origins of Health and Disease* 7, no. 2: 163–171. https://doi.org/10.1017/S2040174415007175.

Chaput, J. P., V. Carson, C. E. Gray, and M. S. Tremblay. 2014. "Importance of all Movement Behaviors in a 24 Hour Period for Overall Health." *International Journal of Environmental Research and Public Health* 11, no. 12: 12575–12581. https://doi.org/10.3390/ijerph111212575.

Chaput, J. P., R. C. Colley, S. Aubert, et al. 2017. "Proportion of Preschool-Aged Children Meeting the Canadian 24-Hour Movement Guidelines and Associations With Adiposity: Results From the Canadian Health Measures Survey." *BMC Public Health* 17, no. Suppl 5: 829.

Chen, X., M. A. Beydoun, and Y. Wang. 2008. "Is Sleep Duration Associated With Childhood Obesity? A Systematic Review and Meta-Analysis." *Obesity* 16: 265–274. https://doi.org/10.1038/oby.2007.63.

Choi, L., C. Beck, Z. Liu, R. Moore, C. E. Matthews, and M. S. Buchowski. 2022. "Process Accelerometer Data for Physical Activity Measurement." Published on 2021-01-22, accessed December 8, 2022, https://cran.r-project.org/web//packages/PhysicalActivity/index.html.

Choi, L., Z. Liu, C. E. Matthews, and M. S. Buchowski. 2011. "Validation of Accelerometer Wear and Nonwear Time Classification Algorithm." *Medicine and Science in Sports and Exercise* 43, no. 2: 357–364.

Cook, C. J., S. J. Howard, G. Scerif, et al. 2019. "Associations of Physical Activity and Gross Motor Skills with Executive Function in Preschool Children From Low-Income South African Settings." *Developmental Science* 22, no. 5: e12820. https://doi.org/10.1111/desc.12820.

Early Start, University of Wollongong. "*Early Years Toolbox*," accessed January 12, 2024a, http://www.eytoolbox.com.au/.

Early Start, University of Wollongong. "*Interpreting Toolbox Data (Preliminary Norms*." accessed January 17, 2024b, http://www.eytoolbox.com.au/toolbox-norms.

Evensen, E., T. Wilsgaard, A. S. Furberg, and G. Skeie. 2016. "Tracking of Overweight and Obesity From Early Childhood to Adolescence in a Population-Based Cohort - The Tromsø Study." *Fit Futures BMC Pediatrics* 16: 64.

Fang, H., M. Quan, T. Zhou, et al. 2017. "Relationship Between Physical Activity and Physical Fitness in Preschool Children: A Cross-Sectional Study." *BioMed Research International* 2017: 9314026. https://doi.org/10.1155/2017/9314026.

Group WMGRS. 2006. "WHO Child Growth Standards Based on Length/Height, Weight and Age." *Acta Paediatrica (Oslo, Norway: 1992)* 450: 76.

Hackman, D. A., R. Gallop, G. W. Evans, and M. J. Farah. 2015. "Socioeconomic Status and Executive Function: Developmental Trajectories and Mediation." *Developmental Science* 18, no. 5: 686–702. https://doi.org/10.1111/desc.12246.

Harris, P. A., R. Taylor, B. L. Minor, et al. 2019. "The REDCap Consortium: Building an International Community of Software Platform Partners." *Journal of Biomedical Informatics* 95: 103208.

Harris, P. A., R. Taylor, R. Thielke, J. Payne, N. Gonzalez, and J. G. Conde. 2009. "Research Electronic Data Capture (REDCap)—A Metadata-Driven Methodology and Workflow Process for Providing Translational Research Informatics Support." *Journal of Biomedical Informatics* 42, no. 2: 377–381.

Haugland, E. S., A. K. O. Nilsen, A. D. Okely, K. N. Aadland, and E. Aadland. 2023. "Multivariate Physical Activity Association Patterns for Fundamental Motor Skills and Physical Fitness in Preschool Children Aged 3–5 Years." *Journal of Sports Sciences* 41, no. 7: 654–667. https://doi.org/10.1080/02640414.2023.2232219.

Howard, S. J., T. Powell, E. Vasseleu, S. Johnstone, and E. Melhuish. 2017. "Enhancing Pre-Schoolers' Executive Functions Through Embedding Cognitive Activities in Shared Book Reading." *Educational Psychology Review* 29, no. 1: 153–174.

Janssen, X., D. P. Cliff, J. J. Reilly, et al. 2013. "Predictive Validity and Classification Accuracy of ActiGraph Energy Expenditure Equations and cut-Points in Young Children." *PLoS ONE* 8, no. 11: e79124.

Joo, J. W., F. Hormozdiari, B. Han, and E. Eskin. 2016. "Multiple Testing Correction in Linear Mixed Models." *Genome Biology* 17: 62. https://doi.org/10.1186/s13059-016-0903-6.

Kuzik, N., V. J. Poitras, M. S. Tremblay, E. Y. Lee, S. Hunter, and V. Carson. 2017. "Systematic Review of the Relationships Between Combinations of Movement Behaviours and Health Indicators in the Early Years (0-4 Years)." *BMC Public Health* 17, no. Suppl 5: 849. https://doi.org/10.1186/s12889-017-4851-1.

Lohman, T. G., A. F. Roche, and R. Martorell. 1988. *Anthropometric Standardization Reference Manual*. Human Kinetics Books.

McNeill, J., S. J. Howard, S. A. Vella, and D. P. Cliff. 2020. "Longitudinal Associations of Physical Activity and Modified Organized Sport Participation With Executive Function and Psychosocial Health in Preschoolers." *Journal of Sports Sciences* 38, no. 24: 2858–2865. https://doi.org/10.1080/02640414.2020.1803037.

Meredith-Jones, K., B. Galland, J. Haszard, et al. 2019. "Do Young Children Consistently Meet 24-H Sleep and Activity Guidelines? A Longitudinal Analysis Using Actigraphy." *International Journal of Obesity* 43, no. 12: 2555–2564.

Miller, A. L., J. C. Lumeng, and M. K. Lebourgeois. 2015. "Sleep Patterns and Obesity in Childhood." *Current Opinion in Endocrinology, Diabetes & Obesity* 22: 41–47. https://doi.org/10.1097/med.0000000000000125.

Miller, M. A., S. Bates, C. Ji, and F. P. Cappuccio. 2021. "Systematic Review and Meta-Analyses of the Relationship Between Short Sleep and Incidence of Obesity and Effectiveness of Sleep Interventions on Weight Gain in Preschool Children." *Obesity Reviews* 22, no. 2: e13113. https://doi.org/10.1111/obr.13113.

Munambah, N., P. Gretschel, F. Muchirahondo, et al. 2021. "24 Hour Movement Behaviours and the Health and Development of Pre-School Children From Zimbabwean Settings: The SUNRISE Pilot Study." *South African Journal of Sports Medicine* 33, no. 1: v33i1a10864.

National Institute of Health. "*NIH Toolbox: Motor Assessment*". accessed January 21, 2024, https://www.nihtoolbox.org/domain/motor/.

Nusurupia, J., J. J. Reilly, and X. Janssen. 2020. "Pre-School Children's Compliance With the WHO 24-Hour Movement Behaviour Guidelines: A Systematic Review of Sub-Saharan African Studies." *African Journal for Physical Activity and Health Sciences* 26, no. 4: 345–359. https://doi.org/10.37597/ajphes.2020.26.4.1.

Okely, T., J. J. Reilly, M. S. Tremblay, et al. 2021. "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* 11, no. 10: e049267. https://doi.org/10.1136/bmjopen-2021-049267.

Pate, R. R., M. J. Almeida, K. L. McIver, K. A. Pfeiffer, and M. Dowda. 2006. "Validation and Calibration of an Accelerometer in Preschool Children." *Obesity (Silver Spring, Md.)* 14, no. 11: 2000–2006. https://doi.org/10.1038/oby.2006.234.

Pate, R. R., J. R. O'Neill, W. H. Brown, K. A. Pfeiffer, M. Dowda, and C. L. Addy. 2015. "Prevalence of Compliance With a New Physical Activity Guideline for Preschool-Age Children." *Childhood Obesity* 11, no. 4: 415–420. https://doi.org/10.1089/chi.2014.0143.

Poitras, V. J., C. E. Gray, X. Janssen, et al. 2017. "Systematic Review of the Relationships Between Sedentary Behaviour and Health Indicators in the Early Years (0-4 Years)." *BMC Public Health* 17, no. Suppl 5: 868. https://doi.org/10.1186/s12889-017-4849-8.

Reuben, D. B., S. Magasi, H. E. McCreath, et al. 2013. "Motor Assessment Using the NIH Toolbox." *Neurology* 80, no. 11 Suppl 3: S65–S75. https://doi.org/10.1212/WNL.0b013e3182872e01.

Rich, C., M. Geraci, L. Griffiths, F. Sera, C. Dezateux, and M. Cortina-Borja. 2014. "Quality Control Methods in Accelerometer Data Processing: Identifying Extreme Counts." *PLoS ONE* 9, no. 1: e85134.

Rollo, S., O. Antsygina, and M. S. Tremblay. 2020. "The Whole Day Matters: Understanding 24-Hour Movement Guideline Adherence and Relationships With Health Indicators Across the Lifespan." *Journal of Sport and Health Science* 9, no. 6: 493–510.

Sanchez-Delgado, G., C. Cadenas-Sanchez, J. Mora-Gonzalez, et al. 2015. "Assessment of Handgrip Strength in Preschool Children Aged 3 to 5 Years." *Journal of Hand Surgery, European Volume* 40, no. 9: 966–972. https://doi.org/10.1177/1753193415592328.

Serrano-Gallén, G., N. M. Arias-Palencia, S. González-Víllora, V. Gil-López, and M. Solera-Martínez. 2022. "The Relationship Between Physical Activity, Physical Fitness and Fatness in 3–6 Years old Boys and Girls: A Cross-Sectional Study." *Translational Pediatrics* 11, no. 7: 1095–1104. https://doi.org/10.21037/tp-22-30.

Team RC. 2022. *R: A Language and Environment for Statistical Computing*. 4.2.2 ed. R Foundation for Statistical Computing.

Team RC. 2023. *R: A Language and Environment for Statistical Computing*. 4.3.1 ed. R Foundation for Statistical Computing.

Tracy, J. D., T. Donnelly, E. C. Sommer, W. J. Heerman, S. L. Barkin, and M. S. Buchowski. 2021. "Identifying Bedrest Using Waist-Worn Triaxial Accelerometers in Preschool Children." *PLoS ONE* 16, no. 1: e0246055.

Tracy, J. D., Z. Xu, L. Choi, S. Acra, K. Y. Chen, and M. S. Buchowski. 2014. "Separating Bedtime Rest From Activity Using Waist or Wrist-Worn Accelerometers in Youth." *PLoS ONE* 9, no. 4: e92512.

Tremblay, M. S. 2020. "Introducing 24-Hour Movement Guidelines for the Early Years: A New Paradigm Gaining Momentum." *Journal of Physical Activity & Health* 17, no. 1: 92–95. https://doi.org/10.1123/jpah.2019-0401.

United Nations International Children's Emergency Fund. 2024. *The State of the World's Children 2023: Statistical Tables*. United Nations International Children's Emergency Fund. accessed April 28, 2024, https://data.unicef.org/resources/sowc-2023/.

Veldman, S. L. C., C. A. Paw, and MJM, Altenburg TM. 2021. "Physical Activity and Prospective Associations With Indicators of Health and Development in Children Aged <5 Years: a Systematic Review." *International Journal of Behavioral Nutrition and Physical Activity* 18: 6. https://doi.org/10.1186/s12966-020-01072-w.

Verswijveren, S. J. J. M., S. A. Wiebe, A. A. Rahman, N. Kuzik, and V. Carson. 2020. "Longitudinal Associations of Sedentary Time and Physical Activity Duration and Patterns With Cognitive Development in Early Childhood." *Mental Health and Physical Activity* 19: 100340. https://doi.org/10.1016/j.mhpa.2020.100340.

von Elm, E., D. G. Altman, M. Egger, and et al. 2007. "The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies." *Lancet* 370, no. 9596: 1453–1457.

Wiersma, R., B. F. Haverkamp, J. H. van Beek, et al. 2020. "Unravelling the Association Between Accelerometer-Derived Physical Activity and Adiposity Among Preschool Children: A Systematic Review and Meta-Analyses." *Obesity Reviews* 21, no. 2: e12936. https://doi.org/10.1111/obr.12936.

Willoughby, M. T., A. C. Wylie, and D. J. Catellier. 2018. "Testing the Association Between Physical Activity and Executive Function Skills in Early Childhood." *Early Childhood Research Quarterly* 44: 82–89. https://doi.org/10.1016/j.ecresq.2018.03.004.

Wipfli, B., S. Wild, C. Donovan, G. C. Hanson, and S. S. Thosar. 2021. "Sedentary Work and Physiological Markers of Health." *International Journal of Environmental Research and Public Health* 18, no. 6: 3230. https://doi.org/10.3390/ijerph18063230.

World Health Organisation. 2018. *Summary Report of the Update of Systematic Reviews of the Evidence to Inform the WHO Guidelines on Physical Activity, Sedentary Behaviour and Sleep in Children Under 5 Years of Age*. World Health Organisation. (WHO/NMH/PND/SPP/18.11). Licence: CC BY-NC-SA 3.0 IGO.

World Health Organisation. 2019. *Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children Under 5 Years of Age*. World Health Organisation. Licence: CC BY-NC-SA 3.0 IGO.