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Levels and Correlates of Objectively Measured Sedentary Behaviour in Young Children: SUNRISE Study Results from 19 Countries

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Levels and Correlates of Objectively Measured Sedentary Behaviour in Young Children: SUNRISE Study Results from 19 Countries

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ABSTRACT

Purpose: There is a paucity of global data on sedentary behaviour during early childhood. The purpose of this study was to examine how device-measured sedentary behaviour in young children differed across geographically, economically, and socio-demographically diverse populations, in an international sample. **Methods:** This multinational, cross-sectional study included data from 1071 3–5-year-old children from 19 countries, collected between 2018 and 2020 (pre-COVID). Sedentary behaviour was measured for three consecutive days using activPAL accelerometers. Sedentary time, sedentary fragmentation and seated transport duration were calculated. Linear mixed models were used to examine the differences in sedentary behaviour variables between sex, country-level income groups, urban/rural settings, and population density. **Results:** Children spent 56% (7.4 hours) of their waking time sedentary. The longest average bout duration was 81.1±45.4 min, and an average of 61.1±50.1 min/day was spent in seated transport. Children from upper-middle-income and high-income countries spent a greater proportion of the day sedentary, accrued more sedentary bouts, had shorter breaks between sedentary bouts, and spent significantly more time in seated transport, than children from low-and lower-middle-income countries. Sex and urban/rural residential setting were not associated with any outcomes. Higher population density was associated with several higher sedentary behaviour measures. **Conclusions:** These data advance our understanding of young children's sedentary behaviour patterns globally. Country income levels and population density appear to be stronger drivers of the observed differences, than sex or rural/urban residential setting.

KEYWORDS: Sitting, Early Years, Socio-demographic Characteristics, Accelerometry.

INTRODUCTION

Sedentary behaviour is recognised as an important risk factor associated with adverse health outcomes in adults (1). While evidence on the health and developmental implications of sedentary behaviour in the early years is inconclusive (2), research suggests an unfavourable association between sedentary behaviour and adiposity, bone mineral content, psychological health and cognitive development in children under the age of four (3). Further, a dose-response relationship between increased sedentary time and poor health outcomes has been observed in school-aged children and youth (4). Considering that sedentary behaviour tracks from early-to-middle childhood at moderate-to-large levels (5) there is a need to investigate sedentary behaviour patterns and correlates in young children.

A recent systematic review examining correlates of sedentary time in young children was unable to identify any consistent correlates, suggesting that further investigation is needed (6). However, there is some evidence to suggest associations between sex and sedentary behaviour, with girls typically more sedentary than boys (7). Both device-measured (8) and self-reported (9) cross-sectional data indicate that rural children are less sedentary than children residing in urban areas. Studies assessing associations between urban population density and sedentary behaviour have shown that older children residing in higher-density urban locations spend significantly more time in sedentary behaviours compared to those in lower-density areas (10).

European (11) and international (12) multi-country device-measured sedentary behaviour data from high-income countries (HIC), suggest that there are substantial differences in 3–5-year-old children's sedentary time. However, limited data are available among young children, particularly from low- and middle-income countries, many of which are experiencing rapid urbanisation (13). A recent systematic review of 50 studies reporting device-measured sedentary behaviour prevalence data among 2-5 year-olds found only one study conducted in an upper-middle-income country (UMIC) and none from low- or lower-middle income countries (LLMICs), with the remaining 49 studies from HICs (7). This highlights a notable gap in our understanding of how sedentary behaviour patterns may differ across geographically, culturally, and economically diverse populations. The dearth of evidence is concerning given that sedentary behaviour is now considered a major public health problem (14), the mounting evidence on the all-cause mortality associated with sitting time (15), and parallel concerns about the considerable contribution of physical inactivity to the global disease burden, 75% of which is borne by LLMICs and UMICs (16). Recent increases in sedentary behaviour and reduced time spent in outside play, attributable to COVID-19 restrictions, among a global sample of young children (17), underscores the need to increase our understanding and generate capacity to respond.

The 2019 WHO's *Guidelines for physical activity, sedentary behaviour and sleep for children under 5 years of age* provides further impetus to investigate sedentary behaviour in this age group (18). While falling short of setting a definitive limit on daily sedentary time, the *WHO Guidelines* recommend that 3- and 4-year-olds should not be restrained for more than one hour at a time (e.g. in prams/strollers) or sit for extended periods. In addition, sedentary screen time should be limited to no more than one hour/day, with less considered better. It is noteworthy that the evidence underpinning the *WHO Guidelines* is almost exclusively based on studies from HICs, further emphasising the need for more internationally diverse data that examine the contextual differences of sedentary behaviour patterns across populations (19).

The aim of this study was to investigate accelerometer-derived sedentary behaviour patterns in a geographically, economically, and culturally diverse international sample of 3–5-year-olds (referred to as 'young children' from here on), and to examine associations with multiple multi-level socio-demographic variables including sex, residential setting, population density and country income classification.

METHODS

Study setting and recruitment

Data used in this study were a sub-set of the SUNRISE pilot study sample (20), an international cross-sectional study of movement behaviours and associated health and developmental outcomes in the early years. Recruitment occurred using convenience cluster sampling through either Early Childhood Education or Care (ECEC) services or from the community, at a village level. Children were eligible to participate if they were aged 3–5 years and typically developing. Data were collected from a sex-balanced sample of up to 100 children, with half typically recruited from urban and rural settings in 19 countries. This sample size has been deemed sufficient to pilot the protocol in each setting.

Ethical approval was obtained from the University of Wollongong, Australia (ref: 2018/044) and the appropriate ethics committee(s) in each country. Data collection occurred between March 2018 and March 2020. Written, informed consent was obtained from all caregivers.

Measures and procedures

Sedentary behaviour

Sedentary time was measured using the activPAL triaxial inclinometer (PAL Technology Ltd., Glasgow, Scotland), suitable for use among young children (21). Worn on the right thigh and held in place with surgical tape, it provides time-stamped data collected at a sampling frequency of 10 Hz. Each child wore the activPAL continuously for three consecutive days (24 h/day), including during water activities and sleeping, to allow for an accurate estimate of habitual movement behaviour (22, 23).

Raw data were processed with the activPAL proprietary algorithms via PALbatch software (v8.10.12; PAL Technologies Ltd., Glasgow, Scotland). Two event files (per child) were generated for the analysis. The first was created using the Standard PAL Analysis Algorithm (VANE), which classifies activity events into three main categories (sitting/lying, standing, stepping) based on the thigh position and dynamic acceleration information. The second was created using the Enhanced Analysis Algorithm (CREA), which quantifies periods of non-wear time (based on a measure of stillness, using a 60min cut-off) and seated transport (based on the presence of dynamic components in the acceleration signals from a sitting event). While the validity remains unclear these algorithms have been used in other studies. Little evidence is currently available regarding the validity of these algorithms for this age group, they are being used in similar research (24), and validation in youth and adults is promising (25).

Visual file inspection identified children with at least one day of 24h data. The VANE event files were then analysed using a custom-made MATLAB program (Sedentariness). Waking hours on each wear day were identified using the built-in algorithm that detects sleep offset and onset times. To avoid misclassification of sedentary behaviour as nocturnal sleep, only the day(s) with at least 8h of waking wear time were considered valid and included in the final analyses. This may have included periods of napping.

Output variables included total time spent sitting or lying, percentage of waking hours spent in sedentary activities, number of bouts lasting >1 min, and the durations of the longest sedentary bout and break. Further, the amount of time children spent in seated transport and whether >60 consecutive minutes were spent on seated transport were calculated. All variables were calculated for each day and then averaged across all valid days for each child for the final analyses. Children with any non-wear time were excluded from the analysis.

Demographics

Demographic data were collected via primary caregiver report in local language as per the SUNRISE protocol (26). Caregivers completed a questionnaire or participated in a face-to-face or telephone interview, particularly if literacy was a barrier to self-report. Demographic variables included age, sex, and residential setting (urban/rural). Due to the absence of an internationally harmonised definition of degree of urbanisation (27), locally relevant criteria (e.g. distance from town, service availability, population density) were used to classify settings as urban or rural. The World Bank's country income level classifications were used to categorise countries as either LLMIC, UMIC or HIC (20). These variables served both a descriptive purpose and were utilised as exposure variables in the analysis of the correlates of sedentary behaviour patterns. The population density of the study sites (ECEC or village) was determined according to authoritative local sources. As population density was not normally distributed, the following categories were used to balance participant numbers for statistical purposes: i) ≤999, ii) 1000-4999, iii) 5000-7499, and iv) ≥7500 population/km^2.

Statistical analysis

Data were pooled from all countries. Linear mixed models were used to assess differences in the continuous measures of sedentary behaviour between i) boys and girls, ii) countries' income levels, iii) residential setting, and iv) population density categories. Similar analyses were conducted on the dichotomous variables using generalised linear mixed models. All models were adjusted for childcare centres/villages and country sites as random effects, and child's age and sex (except for the sex-specific models) as covariates.

RESULTS

Data were drawn from SUNRISE pilot study sites in Australia, Bangladesh, Brazil, Canada, China, Hong Kong, Indonesia, Japan, Korea Republic, Malaysia, Morocco, Papua New Guinea, Scotland, South Africa, Sri Lanka, Sweden, United States, Vietnam, and Zimbabwe. Of the 1207 participating children, 1071 (89%) provided valid accelerometry data for the present analyses. The mean number of valid days was 2.4. Of the sample 10% had one valid day, 43% had two valid days and 46.3% had three valid days. There were eight reports of minor skin irritation following use of the activPAL in Canada, Bangladesh and Australia. See Table 1 for difference in descriptive characteristics between the analytical and excluded sample.

Children spent 56.1% of their daily waking hours (mean=13.2±1.6 h/day) sedentary, equating to 7.4 h/day, and accrued an average of 68±16.9 sitting bouts of longer than 1 min duration. Children's longest sedentary bout lasted an average of 81.1±45.5 min. The longest break between sedentary bouts lasted 25.7±17.2 min on average. Children spent 61.1±50.1 min/day in seated transport and 23.4% of the sample spent >60 consecutive min/day in seated transport. No significant differences were observed between boys and girls for any of the sedentary behaviour variables (See Table 2).

Table 3 reports sedentary behaviour levels and patterns grouped by country income levels. Children from UMICs spent the greatest proportion of their day sedentary, which was significantly higher compared to children from LLMICs (mean difference [MD]=6.3%). The longest overall sedentary bout among children from UMICs was significantly longer compared to both children from LLMICs (MD=28.1 min) and HICs (MD=26.1 min). The longest break between sedentary bouts was significantly shorter among children from HICs compared to children from LLMICs (MD=6.2 min). Children from HICs also spent significantly more time in seated transport compared with children from LLMICs (MD=39.4 min) and UMICs (MD=33.9 min).

No significant differences were observed for any of the outcome variables between children from rural and urban residential settings (See Table 4). Population density within the study sites ranged from 12 people/km^2 in Argyll and Bute, Scotland to 41,000 people/km^2 in Dhaka, Bangladesh. Figure 1 illustrates sedentary behaviour patterns by four population density groupings. As population density increased, from lower density (≤999/km^2) to higher density (>5000km^2), significant increases (all p=<0.0001) in multiple sedentary behaviour variables were noted, including the total time and proportion of the day spent sedentary, the duration of the longest sedentary bout and the total time spent in seated transport (See Table 5).

DISCUSSION

This is the first study to examine device-measured sedentary behaviour among young children across a wide range of countries from LLMICs to HICs. Overall, children from UMICs and HICs spent a greater proportion of the day sedentary, accrued more sedentary bouts, had shorter breaks between sedentary bouts, and spent significantly more time in seated transport than children from LLMICs. Further, an increase in population density was associated with increases in multiple sedentary behaviour measures, particularly the length of sedentary bouts and time spent in seated transport. Benchmarking sedentary behaviour levels and patterns and examining socio-demographic differences in sedentary behaviour is an important first step to provide insights on young children's sedentary behaviour profiles and their alignment with elements of the sedentary behaviour recommendations from the WHO *Guidelines.*

In contrast to existing research undertaken from almost exclusively in HICs examining sex differences in device-measured sedentary behaviour (7), we did not find that boys are less sedentary than girls in the early years. This is perhaps because of the inclusion of data from LLMICs and UMICs in our data set and highlights the need for caution when generalising outcomes based on data from HICs.

A novel finding is the considerable differences in sedentary behaviour levels and patterns between children from the 'lower-middle' compared to the 'upper-middle' income groups.

Countries in these two distinct income categories are often grouped together as one 'middle-income' group, and are frequently also grouped with low-income countries. Our findings show that sedentary behaviour patterns of children from the UMIC category, are much more similar to those of HIC children, suggesting that UMICs may be moving in the same direction as HICs in terms of sedentary behaviour levels and patterns. This could be explained by the increased purchasing power in UMICs compared to LLMIC populations, which may result in the acquisition of products that encourage sedentary behaviour, e.g., tablet/smart phone or motorised transport. Sedentary behaviour may therefore be indirectly valued as an indicator of affluence and prestige and considered socially desirable. This epidemiologic transition has been identified in related fields of research, such as obesity, where it has been shown that in countries in transition, groups with higher incomes are the first to shift to a more sedentary lifestyle before those of lower income (28). Research among adolescents in 68 LMICs, has also reported that increases in a country's economic development were coupled with higher levels of sedentary behaviour among both sexes (29). Our findings provide preliminary evidence of a potential sedentary behaviour transition that appears to begin in early childhood. Research is needed to understand the factors that mediate the relationship between income levels and different types of children's sedentary behaviour in the early years (30).

The considerable differences in sedentary behaviour profiles between young children from LLMICs and UMICs found in our study, would have gone unnoticed in aggregated data analysis. These findings have implications for public health interventions at the UMIC country level, which may not be receiving the required attention.

Our results showed no significant differences in sedentary behaviour between urban and rural residential settings. While this stands in contrast to a small number of existing studies examining within country differences, the local variation in criteria used to classify areas as rural or urban, may explain this finding. When using urban density as a measure to classify a location on the urban-rural continuum for example, urban study sites from some countries (e.g. Ottawa, Canada), fell into a lower population density category compared with some rural study sites (e.g. Ciamis, Indonesia).

The population density analyses revealed a more consistent picture of associations with sedentary behaviour than residential setting. Children from locations with a higher population density were found to spend a greater proportion of the day spent sedentary, accrued a longer duration of sedentary bouts and spent more total time spent in seated transport, compared to those from lower density areas. Studies assessing associations between urban population density and sedentary behaviour have shown that older children residing in higher density locations spend significantly more time in sedentary behaviours compared to those in lower density residential areas (10). Questions arise around which factors are important in this context. Of particular interest are modifiable environmental mediators (e.g. safe outdoor play spaces) as these can bring about sustainable population level changes in behaviour patterns (31). The International Society for Physical Activity and Health in their 'Eight Investments That Work for Physical Activity', specify the need for 'active urban design' and 'active travel'. They call for urban environments with more destinations within shorter distances, better opportunities for walking and cycling and more urban green spaces (32). This is backed by research highlighting the relationship between urban design, transport and health (33). Given the finite nature of waking time in any given 24hr period, we hypothesise that urban environments which foster physical activity in this way may result in reductions in sedentary behaviours (34).

The *WHO Guidelines* recommend that young children should not be restrained for more than 60 min at a time (18). Our data show a clear trend suggesting that as country income increases, so does total time spent in seated transport. This is not unexpected given the greater access to personal vehicles in HICs, and policies and enforcement around seatbelts and other child safety measure in vehicles. This finding is supported by research into active transportation of children in emerging economies which shows that children from poorer families and those who live closer to schools were also consistently more likely to engage in active transportation (35). This trend was further mirrored in our population density analysis which showed that as population density rose above 5000 population/km^2, young children spent a significantly greater total time in seated transport. Although time spent in seated transport is only one element of what constitutes 'restrained sitting' the high rates justify further investigation.

The *WHO Guidelines* also recommend that children under 5 years old should not sit for extended periods. While there is currently no definition for what constitutes prolonged sitting in the early years, there is evidence showing the physiological (36) and cognitive (37) benefits of breaking up sitting periods in adult populations. Given that our data shows that 39% of HIC children spent >60 min/day in seated transport, warrants further research in young children.

A strength of our study is the diverse sample which adds new understanding of sedentary behaviours among young children, particularly in low- and middle-income countries. The use of device measured 24-hr data using an inclinometer is a further strength. This is also the first study to our knowledge that examined associations between sedentary behaviour patterns and country income levels in a global sample. However, despite the diversity of our study sample, a limitation is the relatively small, 3-day convenience sample of pilot data, which, coupled with the cross-sectional design, precludes causal inference. The inability to identify periods of daytime napping is an additional limitation. The lack of a consistent definition of what constitutes a rural and urban setting may be a further weakness. A limitation of device-measured sedentary behaviour is that it is devoid of the context in which the sedentary behaviour occurs. We know that not all sedentary behaviour is equal (e.g., building a puzzle or reading while sedentary is not equal to sitting/lying watching television or restrained in a car seat) but we are not able to comment on or assess these more nuanced aspects of sedentary behaviour.

CONCLUSIONS

Our investigation of levels and correlates of device-measured sedentary time in a diverse international sample of young children, revealed that 56.1% of their daily waking hours were spent sedentary. Our results highlight how children residing in UMICs appear to be exhibiting similar unfavourable sedentary behaviour profiles to children in HICs. Further, our study highlights significant associations between population density and sedentary behaviour levels and patterns, with those living in higher density locations more sedentary. The findings suggest that country income levels and population density appear to be stronger drivers of the observed differences, than sex, or rural/urban residential setting. These important findings warrant further examination with larger sample sizes from diverse settings and regions. It is anticipated that the SUNRISE main studies will generate a highly robust sample from which to draw more generalisable conclusions.

Future analyses of country income level differences in sedentary behaviour patterns should focus on identifying determinants for such differences. Overall, our findings contribute new insights into global socio-demographic factors associated with young children's sedentary behaviour patterns. However, the social and environmental factors that mediate these relationships remain unknown.

CONTRIBUTIONS

All authors contributed to the design and conceptualisation of the study. Katharina E Kariippanon, Kar Hau Chong, Xanne Janssen, Simone A Tomaz, Evelyn HC Ribeiro, Nyaradzai Munambah, and Anthony D Okely contributed to the conceptualisation, drafting, review and approval of the manuscript. Kar Hau Chong conducted the analyses. Cecilia H S Chan, PW Prasad Chathurangana, Catherine E Draper, Asmaa El Hamdouchi, Wong Jyh Eiin, Alex A Florindo, Amy S Ha, Guan Hongyan, Mohammad Sorowar Hossain, Dong Hoon Kim, Thanh Van Kim, Denise Koh, Marie Löf, Bang Nguyen Pham, Bee Koon Poh, John J Reilly, Amanda E Staiano, Adang Suherman, Chiaki Tanaka, Hong Kim Tang, Mark S Tremblay, E. Kipling Webster and V Pujitha Wickramasinghe reviewed and approved the final manuscript.

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DECLARATION OF INTERESTS

The authors have no competing financial or personal interests to declare.

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FIGURE LEGENDS

Figure 1. Sedentary behaviours by population density ($km/^2$).

Figure 1

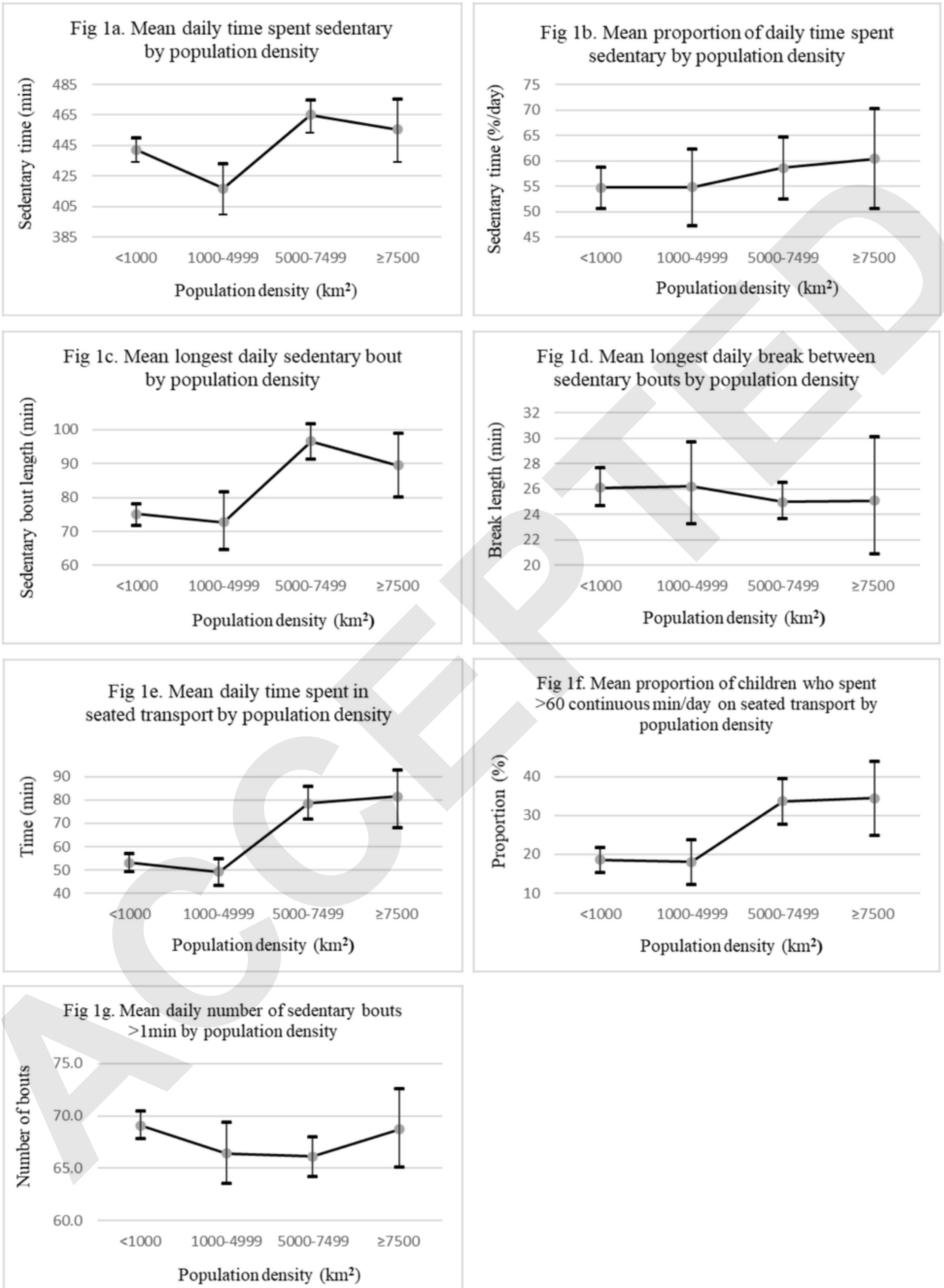
Fig 1a. Mean daily time spent sedentary by population density
Sedentary time (min)
485
465
445
425
405
385
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1b. Mean proportion of daily time spent sedentary by population density
Sedentary time (%/day)
75
70
65
60
55
50
45
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1c. Mean longest daily sedentary bout by population density
Sedentary bout length (min)
100
90
80
70
60
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1d. Mean longest daily break between sedentary bouts by population density
Break length (min)
32
30
28
26
24
22
20
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1e. Mean daily time spent in seated transport by population density
Time (min)
90
80
70
60
50
40
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1f. Mean proportion of children who spent >60 continuous min/day on seated transport by population density
Proportion (%)
40
30
20
10
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1g. Mean daily number of sedentary bouts >1min by population density
Number of bouts
75.0
70.0
65.0
60.0
<1000
1000-4999
5000-7499
≥7500
Population density (km²)

Table 1. Descriptive characteristics of the analytic sample.

	Analytic sample (n=1071)		Excluded sample (n=136)		p-value for comparison
	n	**%**	**n**	**%**	
Age (years) (Mean/SD)[a]	4.5 (0.5)		4.5 (0.5)		0.56
Sex (boys)[b]	553	51.6	64	47.1	0.32
Country income level[b]					
Low- and lower-middle income (LLMIC)	321	30	42	30.9	<0.001
Upper-middle income (UMIC)	358	33.4	66	48.5	
High income (HIC)	392	36.6	28	20.6	
Residential areas[b]					
Urban	537	50.1	82	60.3	0.026
Rural	534	49.9	54	39.7	

Differences between analytic sample and excluded sample were examined using [a]independent samples t-test or [b]Chi-square test.

Table 2. Accelerometer-measured daily sedentary behaviour patterns, grouped by boys and girls.

	All (n=1071)		Boys (n=553)		Girls (n=518)		p-value†
	Mean	SD	Mean	SD	Mean	SD	
Sedentary time (min/d)	444.9	101.4	447.4	106.4	442.2	95.8	0.39
Sedentary time (%/d)	56.1	10.5	56.5	11.1	55.8	9.7	0.24
Bouts > 1 min	68.0	16.9	67.6	18.0	68.3	15.7	0.52
Longest sedentary bout (min)	81.1	45.4	82.9	48.0	79.2	42.4	0.39
Longest break bout (min)	25.7	17.2	25.6	19.7	25.8	14.2	0.94
Total time spent in seated transport (min/d)§	61.1	50.1	62.1	51.6	60.0	48.4	0.17
Spent >60 continuous min/day on seated transport (n/%)#	251	23.4	133	24.1	118	22.8	0.37

Differences between groups (†boys vs girls) were tested using linear mixed models, adjusted for clustering effects (country sites and childcare centre as random effects).

§Analytic sample, n=1009 (522 boys, 487 girls). d refers to waking day. # Reported as M of n and % in place of SD.

Table 3: Sedentary behaviour levels and patterns, grouped by country income levels.

	LLMICs (n=321)		UMICs (n=358)		HICs (n=392)		p-value
	Mean	SD	Mean	SD	Mean	SD	
Sedentary time (min/d)[§]	397.3[a]	102.9	468.8[b]	97.1	462.1[b]	90.5	<0.001
Sedentary time (%/d)[§]	52.0[a]	12.0	58.3[b]	9.8	57.5[a,b]	8.5	0.002
Bouts >1 min (n/d)[§]	66.4	17.7	65.1	15.9	71.9	16.6	0.046
Longest sedentary bout (min/d)[§]	71.0[a]	52.2	99.1[b]	41.9	73.0[a]	37.0	<0.001
Longest break bout (min/d)[§]	28.4[a]	20.8	27.2[a,b]	18.3	22.2[b]	11.5	0.006
Total time spent in seated transport (min/d)[§]	44.8[a]	43.8	50.3[a]	41.6	84.2[b]	53.5	<0.001
Spent >60 continuous min/day on seated transport (n/%)[#*]	43	13.4	54	15.1	154	39.3	0.29

[a,b]Means sharing the different superscript letters are significantly different from each other ($p<0.05$).
Differences between groups were tested using [§]linear mixed models or [#]generalised linear mixed models, adjusted for child's age, sex and clustering effects (childcare centres/villages and country sites as random effects). d refers to waking day. LLMICs = Low- and Lower-Middle-income countries, UMICs = Upper-Middle-income countries, HICs = High-income countries. [*]Reported as M of n and % in place of SD.

Table 4. Sedentary behaviour levels and patterns, grouped by residential setting.

	Urban (n=537)		Rural (n=534)		p-value
	Mean	**SD**	**Mean**	**SD**	
Sedentary time (min/d)§	446.5	101.1	443.3	101.8	0.70
Sedentary time (%/d)§	57.0	10.5	55.3	10.4	0.40
Bouts > 1 min (n/d)§	66.8	16.3	69.2	17.5	0.18
Longest sedentary bout (min/d)§	84.4	45.5	77.8	45.1	0.98
Longest break bout (min/d)§	25.6	15.9	25.9	18.5	0.90
Total time spent in seated transport (min/d)§	68.4	53.8	53.7	44.9	0.18
Spent >60 continuous min/day on seated transport (n/%)#*	155	28.9	96	18	0.91

Differences between groups were tested using §linear mixed models or #generalised linear mixed models, adjusted for child's age, sex and clustering effects (childcare centres/villages and country sites as random effects). d refers to waking day. *Reported as M of n and % in place of SD.

Table 5: Sedentary behaviour levels and patterns, grouped by population density categories.

	Very low <1000/km^2 (n=555)		Low 1000-4999/km^2 (n=167)		Middle 5000-7499/km^2 (n=253)		High ≥7500/km^2 (n=96)		p-value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Sedentary time (min/d)[§]	442.3[a]	102.6	416.9[b]	107.2	465.1[c]	88.4	455.4[a,c]	104.9	<0.001
Sedentary time (%/d)[§]	54.7[a]	10.8	54.8[a]	11.2	58.6[b]	8.3	60.4[b]	9.8	<0.001
Bouts >1 min (n/d)[§]	69.1	16.6	66.4	18.9	66.1	15.6	68.7	18.3	0.07
Longest sedentary bout (min/d)[§]	75.2[a]	40.0	72.7[a]	56.4	96.6[b]	43.0	89.5[b]	48.9	<0.001
Longest break bout (min/d)[§]	26.1	16.8	26.2	21.1	25.0	11.0	25.1	24.2	0.78
Total time spent in seated transport (min/d)[§]	53.1[a]	45.0	49.3[a]	38.6	78.5[b]	54.4	81.4[b]	64.7	<0.001
Spent >60 continuous min/day on seated transport (n/%)[#*]	103	18.6	30	18.0	85	33.6	33	34.4	0.76

[a,b,c] Means sharing the different superscript letters are significantly different from each other ($p<0.05$). Differences between groups were tested using [§]linear mixed models or [#]generalised linear mixed models, adjusted for child's age, sex and clustering effects (childcare centres/villages and country sites as random effects). d refers to waking day. [*]Reported as M of n and % in place of SD.

Levels and Correlates of Objectively Measured Sedentary Behaviour in Young Children: SUNRISE Study Results from 19 Countries

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ABSTRACT

Purpose: There is a paucity of global data on sedentary behaviour during early childhood. The purpose of this study was to examine how device-measured sedentary behaviour in young children differed across geographically, economically, and socio-demographically diverse populations, in an international sample. **Methods:** This multinational, cross-sectional study included data from 1071 3–5-year-old children from 19 countries, collected between 2018 and 2020 (pre-COVID). Sedentary behaviour was measured for three consecutive days using activPAL accelerometers. Sedentary time, sedentary fragmentation and seated transport duration were calculated. Linear mixed models were used to examine the differences in sedentary behaviour variables between sex, country-level income groups, urban/rural settings, and population density. **Results:** Children spent 56% (7.4 hours) of their waking time sedentary. The longest average bout duration was 81.1±45.4 min, and an average of 61.1±50.1 min/day was spent in seated transport. Children from upper-middle-income and high-income countries spent a greater proportion of the day sedentary, accrued more sedentary bouts, had shorter breaks between sedentary bouts, and spent significantly more time in seated transport, than children from low-and lower-middle-income countries. Sex and urban/rural residential setting were not associated with any outcomes. Higher population density was associated with several higher sedentary behaviour measures. **Conclusions:** These data advance our understanding of young children's sedentary behaviour patterns globally. Country income levels and population density appear to be stronger drivers of the observed differences, than sex or rural/urban residential setting.

KEYWORDS: Sitting, Early Years, Socio-demographic Characteristics, Accelerometry.

INTRODUCTION

Sedentary behaviour is recognised as an important risk factor associated with adverse health outcomes in adults (1). While evidence on the health and developmental implications of sedentary behaviour in the early years is inconclusive (2), research suggests an unfavourable association between sedentary behaviour and adiposity, bone mineral content, psychological health and cognitive development in children under the age of four (3). Further, a dose-response relationship between increased sedentary time and poor health outcomes has been observed in school-aged children and youth (4). Considering that sedentary behaviour tracks from early-to-middle childhood at moderate-to-large levels (5) there is a need to investigate sedentary behaviour patterns and correlates in young children.

A recent systematic review examining correlates of sedentary time in young children was unable to identify any consistent correlates, suggesting that further investigation is needed (6). However, there is some evidence to suggest associations between sex and sedentary behaviour, with girls typically more sedentary than boys (7). Both device-measured (8) and self-reported (9) cross-sectional data indicate that rural children are less sedentary than children residing in urban areas. Studies assessing associations between urban population density and sedentary behaviour have shown that older children residing in higher-density urban locations spend significantly more time in sedentary behaviours compared to those in lower-density areas (10).

European (11) and international (12) multi-country device-measured sedentary behaviour data from high-income countries (HIC), suggest that there are substantial differences in 3–5-year-old children's sedentary time. However, limited data are available among young children, particularly from low- and middle-income countries, many of which are experiencing rapid urbanisation (13). A recent systematic review of 50 studies reporting device-measured sedentary behaviour prevalence data among 2-5 year-olds found only one study conducted in an upper-middle-income country (UMIC) and none from low- or lower-middle income countries (LLMICs), with the remaining 49 studies from HICs (7). This highlights a notable gap in our understanding of how sedentary behaviour patterns may differ across geographically, culturally, and economically diverse populations. The dearth of evidence is concerning given that sedentary behaviour is now considered a major public health problem (14), the mounting evidence on the all-cause mortality associated with sitting time (15), and parallel concerns about the considerable contribution of physical inactivity to the global disease burden, 75% of which is borne by LLMICs and UMICs (16). Recent increases in sedentary behaviour and reduced time spent in outside play, attributable to COVID-19 restrictions, among a global sample of young children (17), underscores the need to increase our understanding and generate capacity to respond.

The 2019 WHO's *Guidelines for physical activity, sedentary behaviour and sleep for children under 5 years of age* provides further impetus to investigate sedentary behaviour in this age group (18). While falling short of setting a definitive limit on daily sedentary time, the *WHO Guidelines* recommend that 3- and 4-year-olds should not be restrained for more than one hour at a time (e.g. in prams/strollers) or sit for extended periods. In addition, sedentary screen time should be limited to no more than one hour/day, with less considered better. It is noteworthy that the evidence underpinning the *WHO Guidelines* is almost exclusively based on studies from HICs, further emphasising the need for more internationally diverse data that examine the contextual differences of sedentary behaviour patterns across populations (19).

The aim of this study was to investigate accelerometer-derived sedentary behaviour patterns in a geographically, economically, and culturally diverse international sample of 3–5-year-olds (referred to as 'young children' from here on), and to examine associations with multiple multi-level socio-demographic variables including sex, residential setting, population density and country income classification.

METHODS

Study setting and recruitment

Data used in this study were a sub-set of the SUNRISE pilot study sample (20), an international cross-sectional study of movement behaviours and associated health and developmental outcomes in the early years. Recruitment occurred using convenience cluster sampling through either Early Childhood Education or Care (ECEC) services or from the community, at a village level. Children were eligible to participate if they were aged 3–5 years and typically developing. Data were collected from a sex-balanced sample of up to 100 children, with half typically recruited from urban and rural settings in 19 countries. This sample size has been deemed sufficient to pilot the protocol in each setting.

Ethical approval was obtained from the University of Wollongong, Australia (ref: 2018/044) and the appropriate ethics committee(s) in each country. Data collection occurred between March 2018 and March 2020. Written, informed consent was obtained from all caregivers.

Measures and procedures

Sedentary behaviour

Sedentary time was measured using the activPAL triaxial inclinometer (PAL Technology Ltd., Glasgow, Scotland), suitable for use among young children (21). Worn on the right thigh and held in place with surgical tape, it provides time-stamped data collected at a sampling frequency of 10 Hz. Each child wore the activPAL continuously for three consecutive days (24 h/day), including during water activities and sleeping, to allow for an accurate estimate of habitual movement behaviour (22, 23).

Raw data were processed with the activPAL proprietary algorithms via PALbatch software (v8.10.12; PAL Technologies Ltd., Glasgow, Scotland). Two event files (per child) were generated for the analysis. The first was created using the Standard PAL Analysis Algorithm (VANE), which classifies activity events into three main categories (sitting/lying, standing, stepping) based on the thigh position and dynamic acceleration information. The second was created using the Enhanced Analysis Algorithm (CREA), which quantifies periods of non-wear time (based on a measure of stillness, using a 60min cut-off) and seated transport (based on the presence of dynamic components in the acceleration signals from a sitting event). While the validity remains unclear these algorithms have been used in other studies. Little evidence is currently available regarding the validity of these algorithms for this age group, they are being used in similar research (24), and validation in youth and adults is promising (25).

Visual file inspection identified children with at least one day of 24h data. The VANE event files were then analysed using a custom-made MATLAB program (Sedentariness). Waking hours on each wear day were identified using the built-in algorithm that detects sleep offset and onset times. To avoid misclassification of sedentary behaviour as nocturnal sleep, only the day(s) with at least 8h of waking wear time were considered valid and included in the final analyses. This may have included periods of napping.

Output variables included total time spent sitting or lying, percentage of waking hours spent in sedentary activities, number of bouts lasting >1 min, and the durations of the longest sedentary bout and break. Further, the amount of time children spent in seated transport and whether >60 consecutive minutes were spent on seated transport were calculated. All variables were calculated for each day and then averaged across all valid days for each child for the final analyses. Children with any non-wear time were excluded from the analysis.

Demographics

Demographic data were collected via primary caregiver report in local language as per the SUNRISE protocol (26). Caregivers completed a questionnaire or participated in a face-to-face or telephone interview, particularly if literacy was a barrier to self-report. Demographic variables included age, sex, and residential setting (urban/rural). Due to the absence of an internationally harmonised definition of degree of urbanisation (27), locally relevant criteria (e.g. distance from town, service availability, population density) were used to classify settings as urban or rural. The World Bank's country income level classifications were used to categorise countries as either LLMIC, UMIC or HIC (20). These variables served both a descriptive purpose and were utilised as exposure variables in the analysis of the correlates of sedentary behaviour patterns. The population density of the study sites (ECEC or village) was determined according to authoritative local sources. As population density was not normally distributed, the following categories were used to balance participant numbers for statistical purposes: i) ≤999, ii) 1000-4999, iii) 5000-7499, and iv) ≥7500 population/km^2.

Statistical analysis

Data were pooled from all countries. Linear mixed models were used to assess differences in the continuous measures of sedentary behaviour between i) boys and girls, ii) countries' income levels, iii) residential setting, and iv) population density categories. Similar analyses were conducted on the dichotomous variables using generalised linear mixed models. All models were adjusted for childcare centres/villages and country sites as random effects, and child's age and sex (except for the sex-specific models) as covariates.

RESULTS

Data were drawn from SUNRISE pilot study sites in Australia, Bangladesh, Brazil, Canada, China, Hong Kong, Indonesia, Japan, Korea Republic, Malaysia, Morocco, Papua New Guinea, Scotland, South Africa, Sri Lanka, Sweden, United States, Vietnam, and Zimbabwe. Of the 1207 participating children, 1071 (89%) provided valid accelerometry data for the present analyses. The mean number of valid days was 2.4. Of the sample 10% had one valid day, 43% had two valid days and 46.3% had three valid days. There were eight reports of minor skin irritation following use of the activPAL in Canada, Bangladesh and Australia. See Table 1 for difference in descriptive characteristics between the analytical and excluded sample.

Children spent 56.1% of their daily waking hours (mean=13.2±1.6 h/day) sedentary, equating to 7.4 h/day, and accrued an average of 68±16.9 sitting bouts of longer than 1 min duration. Children's longest sedentary bout lasted an average of 81.1±45.5 min. The longest break between sedentary bouts lasted 25.7±17.2 min on average. Children spent 61.1±50.1 min/day in seated transport and 23.4% of the sample spent >60 consecutive min/day in seated transport. No significant differences were observed between boys and girls for any of the sedentary behaviour variables (See Table 2).

Table 3 reports sedentary behaviour levels and patterns grouped by country income levels. Children from UMICs spent the greatest proportion of their day sedentary, which was significantly higher compared to children from LLMICs (mean difference [MD]=6.3%). The longest overall sedentary bout among children from UMICs was significantly longer compared to both children from LLMICs (MD=28.1 min) and HICs (MD=26.1 min). The longest break between sedentary bouts was significantly shorter among children from HICs compared to children from LLMICs (MD=6.2 min). Children from HICs also spent significantly more time in seated transport compared with children from LLMICs (MD=39.4 min) and UMICs (MD=33.9 min).

No significant differences were observed for any of the outcome variables between children from rural and urban residential settings (See Table 4). Population density within the study sites ranged from 12 people/km^2 in Argyll and Bute, Scotland to 41,000 people/km^2 in Dhaka, Bangladesh. Figure 1 illustrates sedentary behaviour patterns by four population density groupings. As population density increased, from lower density (≤999/km^2) to higher density (>5000km^2), significant increases (all p=<0.0001) in multiple sedentary behaviour variables were noted, including the total time and proportion of the day spent sedentary, the duration of the longest sedentary bout and the total time spent in seated transport (See Table 5).

DISCUSSION

This is the first study to examine device-measured sedentary behaviour among young children across a wide range of countries from LLMICs to HICs. Overall, children from UMICs and HICs spent a greater proportion of the day sedentary, accrued more sedentary bouts, had shorter breaks between sedentary bouts, and spent significantly more time in seated transport than children from LLMICs. Further, an increase in population density was associated with increases in multiple sedentary behaviour measures, particularly the length of sedentary bouts and time spent in seated transport. Benchmarking sedentary behaviour levels and patterns and examining socio-demographic differences in sedentary behaviour is an important first step to provide insights on young children's sedentary behaviour profiles and their alignment with elements of the sedentary behaviour recommendations from the WHO *Guidelines.*

In contrast to existing research undertaken from almost exclusively in HICs examining sex differences in device-measured sedentary behaviour (7), we did not find that boys are less sedentary than girls in the early years. This is perhaps because of the inclusion of data from LLMICs and UMICs in our data set and highlights the need for caution when generalising outcomes based on data from HICs.

A novel finding is the considerable differences in sedentary behaviour levels and patterns between children from the 'lower-middle' compared to the 'upper-middle' income groups.

Countries in these two distinct income categories are often grouped together as one 'middle-income' group, and are frequently also grouped with low-income countries. Our findings show that sedentary behaviour patterns of children from the UMIC category, are much more similar to those of HIC children, suggesting that UMICs may be moving in the same direction as HICs in terms of sedentary behaviour levels and patterns. This could be explained by the increased purchasing power in UMICs compared to LLMIC populations, which may result in the acquisition of products that encourage sedentary behaviour, e.g., tablet/smart phone or motorised transport. Sedentary behaviour may therefore be indirectly valued as an indicator of affluence and prestige and considered socially desirable. This epidemiologic transition has been identified in related fields of research, such as obesity, where it has been shown that in countries in transition, groups with higher incomes are the first to shift to a more sedentary lifestyle before those of lower income (28). Research among adolescents in 68 LMICs, has also reported that increases in a country's economic development were coupled with higher levels of sedentary behaviour among both sexes (29). Our findings provide preliminary evidence of a potential sedentary behaviour transition that appears to begin in early childhood. Research is needed to understand the factors that mediate the relationship between income levels and different types of children's sedentary behaviour in the early years (30).

The considerable differences in sedentary behaviour profiles between young children from LLMICs and UMICs found in our study, would have gone unnoticed in aggregated data analysis. These findings have implications for public health interventions at the UMIC country level, which may not be receiving the required attention.

Our results showed no significant differences in sedentary behaviour between urban and rural residential settings. While this stands in contrast to a small number of existing studies examining within country differences, the local variation in criteria used to classify areas as rural or urban, may explain this finding. When using urban density as a measure to classify a location on the urban-rural continuum for example, urban study sites from some countries (e.g. Ottawa, Canada), fell into a lower population density category compared with some rural study sites (e.g. Ciamis, Indonesia).

The population density analyses revealed a more consistent picture of associations with sedentary behaviour than residential setting. Children from locations with a higher population density were found to spend a greater proportion of the day spent sedentary, accrued a longer duration of sedentary bouts and spent more total time spent in seated transport, compared to those from lower density areas. Studies assessing associations between urban population density and sedentary behaviour have shown that older children residing in higher density locations spend significantly more time in sedentary behaviours compared to those in lower density residential areas (10). Questions arise around which factors are important in this context. Of particular interest are modifiable environmental mediators (e.g. safe outdoor play spaces) as these can bring about sustainable population level changes in behaviour patterns (31). The International Society for Physical Activity and Health in their 'Eight Investments That Work for Physical Activity', specify the need for 'active urban design' and 'active travel'. They call for urban environments with more destinations within shorter distances, better opportunities for walking and cycling and more urban green spaces (32). This is backed by research highlighting the relationship between urban design, transport and health (33). Given the finite nature of waking time in any given 24hr period, we hypothesise that urban environments which foster physical activity in this way may result in reductions in sedentary behaviours (34).

The *WHO Guidelines* recommend that young children should not be restrained for more than 60 min at a time (18). Our data show a clear trend suggesting that as country income increases, so does total time spent in seated transport. This is not unexpected given the greater access to personal vehicles in HICs, and policies and enforcement around seatbelts and other child safety measure in vehicles. This finding is supported by research into active transportation of children in emerging economies which shows that children from poorer families and those who live closer to schools were also consistently more likely to engage in active transportation (35). This trend was further mirrored in our population density analysis which showed that as population density rose above 5000 population/km^2, young children spent a significantly greater total time in seated transport. Although time spent in seated transport is only one element of what constitutes 'restrained sitting' the high rates justify further investigation.

The *WHO Guidelines* also recommend that children under 5 years old should not sit for extended periods. While there is currently no definition for what constitutes prolonged sitting in the early years, there is evidence showing the physiological (36) and cognitive (37) benefits of breaking up sitting periods in adult populations. Given that our data shows that 39% of HIC children spent >60 min/day in seated transport, warrants further research in young children.

A strength of our study is the diverse sample which adds new understanding of sedentary behaviours among young children, particularly in low- and middle-income countries. The use of device measured 24-hr data using an inclinometer is a further strength. This is also the first study to our knowledge that examined associations between sedentary behaviour patterns and country income levels in a global sample. However, despite the diversity of our study sample, a limitation is the relatively small, 3-day convenience sample of pilot data, which, coupled with the cross-sectional design, precludes causal inference. The inability to identify periods of daytime napping is an additional limitation. The lack of a consistent definition of what constitutes a rural and urban setting may be a further weakness. A limitation of device-measured sedentary behaviour is that it is devoid of the context in which the sedentary behaviour occurs. We know that not all sedentary behaviour is equal (e.g., building a puzzle or reading while sedentary is not equal to sitting/lying watching television or restrained in a car seat) but we are not able to comment on or assess these more nuanced aspects of sedentary behaviour.

CONCLUSIONS

Our investigation of levels and correlates of device-measured sedentary time in a diverse international sample of young children, revealed that 56.1% of their daily waking hours were spent sedentary. Our results highlight how children residing in UMICs appear to be exhibiting similar unfavourable sedentary behaviour profiles to children in HICs. Further, our study highlights significant associations between population density and sedentary behaviour levels and patterns, with those living in higher density locations more sedentary. The findings suggest that country income levels and population density appear to be stronger drivers of the observed differences, than sex, or rural/urban residential setting. These important findings warrant further examination with larger sample sizes from diverse settings and regions. It is anticipated that the SUNRISE main studies will generate a highly robust sample from which to draw more generalisable conclusions.

Future analyses of country income level differences in sedentary behaviour patterns should focus on identifying determinants for such differences. Overall, our findings contribute new insights into global socio-demographic factors associated with young children's sedentary behaviour patterns. However, the social and environmental factors that mediate these relationships remain unknown.

CONTRIBUTIONS

All authors contributed to the design and conceptualisation of the study. Katharina E Kariippanon, Kar Hau Chong, Xanne Janssen, Simone A Tomaz, Evelyn HC Ribeiro, Nyaradzai Munambah, and Anthony D Okely contributed to the conceptualisation, drafting, review and approval of the manuscript. Kar Hau Chong conducted the analyses. Cecilia H S Chan, PW Prasad Chathurangana, Catherine E Draper, Asmaa El Hamdouchi, Wong Jyh Eiin, Alex A Florindo, Amy S Ha, Guan Hongyan, Mohammad Sorowar Hossain, Dong Hoon Kim, Thanh Van Kim, Denise Koh, Marie Löf, Bang Nguyen Pham, Bee Koon Poh, John J Reilly, Amanda E Staiano, Adang Suherman, Chiaki Tanaka, Hong Kim Tang, Mark S Tremblay, E. Kipling Webster and V Pujitha Wickramasinghe reviewed and approved the final manuscript.

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DECLARATION OF INTERESTS

The authors have no competing financial or personal interests to declare.

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FIGURE LEGENDS

Figure 1. Sedentary behaviours by population density ($km/^2$).

Figure 1

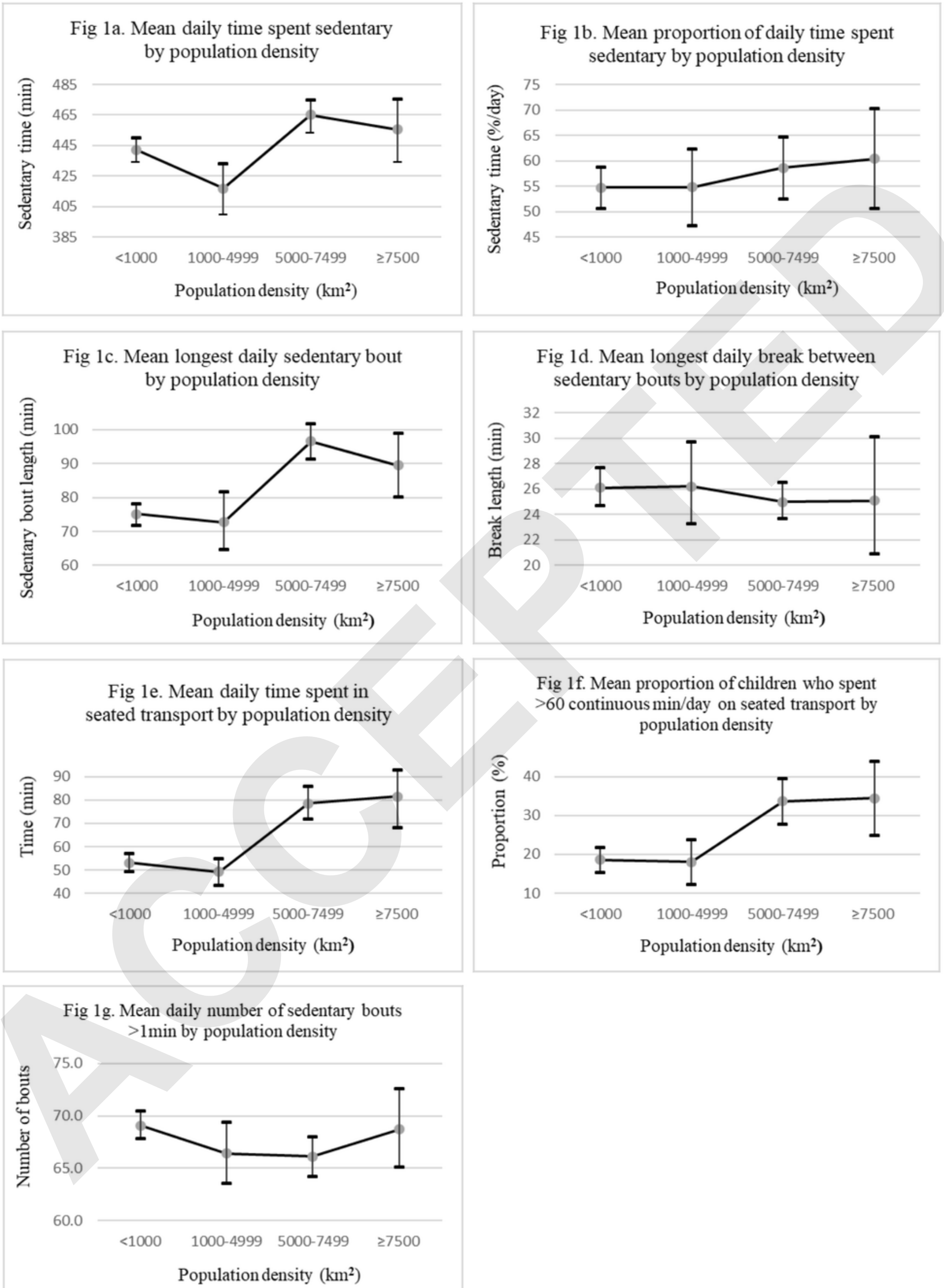
Fig 1a. Mean daily time spent sedentary by population density
Sedentary time (min)
485
465
445
425
405
385
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1b. Mean proportion of daily time spent sedentary by population density
Sedentary time (%/day)
75
70
65
60
55
50
45
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1c. Mean longest daily sedentary bout by population density
Sedentary bout length (min)
100
90
80
70
60
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1d. Mean longest daily break between sedentary bouts by population density
Break length (min)
32
30
28
26
24
22
20
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1e. Mean daily time spent in seated transport by population density
Time (min)
90
80
70
60
50
40
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1f. Mean proportion of children who spent >60 continuous min/day on seated transport by population density
Proportion (%)
40
30
20
10
<1000
1000-4999
5000-7499
≥7500
Population density (km²)
Fig 1g. Mean daily number of sedentary bouts >1min by population density
Number of bouts
75.0
70.0
65.0
60.0
<1000
1000-4999
5000-7499
≥7500
Population density (km²)

Table 1. Descriptive characteristics of the analytic sample.

	Analytic sample (n=1071)		Excluded sample (n=136)		p-value for comparison
	n	**%**	**n**	**%**	
Age (years) (Mean/SD)[a]	4.5 (0.5)		4.5 (0.5)		0.56
Sex (boys)[b]	553	51.6	64	47.1	0.32
Country income level[b]					
Low- and lower-middle income (LLMIC)	321	30	42	30.9	<0.001
Upper-middle income (UMIC)	358	33.4	66	48.5	
High income (HIC)	392	36.6	28	20.6	
Residential areas[b]					
Urban	537	50.1	82	60.3	0.026
Rural	534	49.9	54	39.7	

Differences between analytic sample and excluded sample were examined using [a]independent samples t-test or [b]Chi-square test.

Table 2. Accelerometer-measured daily sedentary behaviour patterns, grouped by boys and girls.

	All (n=1071)		Boys (n=553)		Girls (n=518)		p-value†
	Mean	SD	Mean	SD	Mean	SD	
Sedentary time (min/d)	444.9	101.4	447.4	106.4	442.2	95.8	0.39
Sedentary time (%/d)	56.1	10.5	56.5	11.1	55.8	9.7	0.24
Bouts > 1 min	68.0	16.9	67.6	18.0	68.3	15.7	0.52
Longest sedentary bout (min)	81.1	45.4	82.9	48.0	79.2	42.4	0.39
Longest break bout (min)	25.7	17.2	25.6	19.7	25.8	14.2	0.94
Total time spent in seated transport (min/d)§	61.1	50.1	62.1	51.6	60.0	48.4	0.17
Spent >60 continuous min/day on seated transport (n/%)#	251	23.4	133	24.1	118	22.8	0.37

Differences between groups (†boys vs girls) were tested using linear mixed models, adjusted for clustering effects (country sites and childcare centre as random effects).

§Analytic sample, n=1009 (522 boys, 487 girls). d refers to waking day. # Reported as M of n and % in place of SD.

Table 3: Sedentary behaviour levels and patterns, grouped by country income levels.

	LLMICs (n=321)		UMICs (n=358)		HICs (n=392)		p-value
	Mean	SD	Mean	SD	Mean	SD	
Sedentary time (min/d)[§]	397.3[a]	102.9	468.8[b]	97.1	462.1[b]	90.5	<0.001
Sedentary time (%/d)[§]	52.0[a]	12.0	58.3[b]	9.8	57.5[a,b]	8.5	0.002
Bouts >1 min (n/d)[§]	66.4	17.7	65.1	15.9	71.9	16.6	0.046
Longest sedentary bout (min/d)[§]	71.0[a]	52.2	99.1[b]	41.9	73.0[a]	37.0	<0.001
Longest break bout (min/d)[§]	28.4[a]	20.8	27.2[a,b]	18.3	22.2[b]	11.5	0.006
Total time spent in seated transport (min/d)[§]	44.8[a]	43.8	50.3[a]	41.6	84.2[b]	53.5	<0.001
Spent >60 continuous min/day on seated transport (n/%)[#*]	43	13.4	54	15.1	154	39.3	0.29

[a,b]Means sharing the different superscript letters are significantly different from each other (p<0.05).
Differences between groups were tested using [§]linear mixed models or [#]generalised linear mixed models, adjusted for child's age, sex and clustering effects (childcare centres/villages and country sites as random effects). d refers to waking day. LLMICs = Low- and Lower-Middle-income countries, UMICs = Upper-Middle-income countries, HICs = High-income countries. [*]Reported as M of n and % in place of SD.

Table 4. Sedentary behaviour levels and patterns, grouped by residential setting.

	Urban (n=537)		Rural (n=534)		p-value
	Mean	SD	Mean	SD	
Sedentary time (min/d)§	446.5	101.1	443.3	101.8	0.70
Sedentary time (%/d)§	57.0	10.5	55.3	10.4	0.40
Bouts > 1 min (n/d)§	66.8	16.3	69.2	17.5	0.18
Longest sedentary bout (min/d)§	84.4	45.5	77.8	45.1	0.98
Longest break bout (min/d)§	25.6	15.9	25.9	18.5	0.90
Total time spent in seated transport (min/d)§	68.4	53.8	53.7	44.9	0.18
Spent >60 continuous min/day on seated transport (n/%)#*	155	28.9	96	18	0.91

Differences between groups were tested using §linear mixed models or #generalised linear mixed models, adjusted for child's age, sex and clustering effects (childcare centres/villages and country sites as random effects). d refers to waking day. *Reported as M of n and % in place of SD.

Table 5: Sedentary behaviour levels and patterns, grouped by population density categories.

	Very low <1000/km^2 (n=555)		Low 1000-4999/km^2 (n=167)		Middle 5000-7499/km^2 (n=253)		High ≥7500/km^2 (n=96)		p-value
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	
Sedentary time (min/d)[§]	442.3[a]	102.6	416.9[b]	107.2	465.1[c]	88.4	455.4[a,c]	104.9	<0.001
Sedentary time (%/d)[§]	54.7[a]	10.8	54.8[a]	11.2	58.6[b]	8.3	60.4[b]	9.8	<0.001
Bouts >1 min (n/d)[§]	69.1	16.6	66.4	18.9	66.1	15.6	68.7	18.3	0.07
Longest sedentary bout (min/d)[§]	75.2[a]	40.0	72.7[a]	56.4	96.6[b]	43.0	89.5[b]	48.9	<0.001
Longest break bout (min/d)[§]	26.1	16.8	26.2	21.1	25.0	11.0	25.1	24.2	0.78
Total time spent in seated transport (min/d)[§]	53.1[a]	45.0	49.3[a]	38.6	78.5[b]	54.4	81.4[b]	64.7	<0.001
Spent >60 continuous min/day on seated transport (n/%)[#*]	103	18.6	30	18.0	85	33.6	33	34.4	0.76

[a,b,c] Means sharing the different superscript letters are significantly different from each other ($p<0.05$). Differences between groups were tested using [§]linear mixed models or [#]generalised linear mixed models, adjusted for child's age, sex and clustering effects (childcare centres/villages and country sites as random effects). d refers to waking day. [*]Reported as M of n and % in place of SD.