Research Square

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Global effect of COVID-19 pandemic on physical activity, sedentary behaviour and sleep among 3- to 5-year-old children: a longitudinal study of 14 countries

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Research Article

Keywords: 24-hour movement behaviours, low- and middle-income countries, preschool, outdoors, play, quarantine.

Posted Date: December 10th, 2020

DOI: https://doi.org/10.21203/rs.3.rs-112453/v1

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Abstract

Background: The 2020 COVID-19 pandemic has placed unprecedented restrictions on children's ability to participate in adequate movement behaviours. This international longitudinal study compared young children's physical activity, sedentary behaviour and sleep behaviours before and during the COVID-19 pandemic.

Methods: Parents of children aged 3-5 years, from 14 countries (8 low- and middle-income countries, LMICs) completed surveys to assess changes in physical activity, sedentary behaviour (screen-time) and sleep and how these changes were associated with the COVID-19 pandemic. Surveys were completed in the 12 months up to March 2020 and again between May and June 2020 (at the height of restrictions). PA, sedentary screen time (SST) and sleep were assessed via parent questionnaire. At Time 2, COVID-19 factors including level of restriction, environmental conditions, and parental stress were measured.

Results: 948 parents completed the survey at both time points. Children from LMICs were more likely to meet the PA (AdjOR=2.0, 95%CI 1.0 to 3.8) and SST (2.2, CI 1.2 to 3.9) guidelines than their high-income country (HIC) counterparts. Children who could go outside during COVID-19 were more likely to meet all WHO recommendations (AdjOR 3.3, CI 1.1 to 9.8) than those who were not. Children of caregivers with higher compared to lower stress were less likely to meet all three guidelines (0.5, CI 0.3 to 0.9).

Conclusion: PA and SST levels of children from LMICs have been less impacted by COVID-19 than in HICs. Ensuring children can access an outdoor space, and supporting caregivers' mental health are important prevention strategies.

Introduction

With the emergence of the novel Coronavirus Disease (COVID-19) in 2019 and subsequent global pandemic declared by the WHO in March 2020, governments implemented strategies to prevent the spread of the virus and protect their citizens. In most nations, physical distancing measures and requirements to remain at home placed unprecedented restrictions on children's ability to be active. While these measures were essential to protect the public's health, some unintended consequences may have resulted from these restrictions[1].

Appropriate levels of movement behaviours promote health[2–4], are a powerful antidote to stress and prevent viral infections[5]. Throughout a typical day, young children's movement includes sleep, sitting, standing, and different intensities of physical activity, the latter mostly in the form of play. In 2019, the WHO released global guidelines for these behaviours for children under 5 years of age[6]. The guidelines recommend that pre-school children (aged 3 and 4 years) accumulate at least 180 min physical activity – of which at least 60 min should be at moderate- to vigorous-intensity, engage in no more than 1 h sedentary screen time, and have 10–13 h good-quality sleep per day[6].

A significant change in young children's lives during the COVID-19 restrictions is that they are not attending their usual places of early childhood education and care. Whether children have been able to meet movement behaviour guidelines during this time of COVID-19 restrictions is unknown, but it has been suggested that the flow-on effect of the restrictions may have considerable consequences for young children's ability to maintain a healthy balance of movement behaviours[7].

Over a 12-month period preceding the COVID-19 pandemic, we collected data on preschool children's movement behaviours in predominantly low- and middle-income countries (LMICs). This provided a baseline from which to determine the impact of the pandemic on children's movement behaviours. The aim of this study was to examine how, compared with the time period pre-COVID, the COVID-19 pandemic influenced physical activity, sedentary behaviour, screen time, and sleep among pre-schoolers. Further, the study sought to examine the relationship between COVID-related restriction levels, parent and family factors, and changes in young children's physical activity, sedentary behaviour and sleep. We hypothesized that there would be i) increases in screen time, ii) decreases in physical activity, iii) changes in sleep patterns, and iv) that changes in movement behaviours would be associated with specific family and community-level COVID-19 factors.

Methods

Study design

Prior to the COVID-19 pandemic, 14 countries (8 LMICs) collected data between April 2019 and March 2020 as part of the SUNRISE pilot study (https://sunrise-study.com) to determine the proportion of 3- and 4-year-old children who met the WHO global guidelines. These countries conducted follow-up data collected between May-June 2020, with participants reporting on their experience at the height of prevention and control measures in their respective countries.

The research was performed in accordance with the Declaration of Helsinki. Overall research approval for the study was obtained from the Human Research Ethics Committee (Ref: 2018/044) from the University of Wollongong, Australia. Each wave of data collection was approved by the relevant Human Research Ethics Committees in each participating country.

Setting

Data were collected by local research teams in urban and rural settings, with participants recruited via early childhood education and care (ECEC) services and villages. At Time 1 (T1), caregiver surveys were either self-administered by parents or, if there were literacy barriers, via interview. Follow-up (Time 2, T2) data collection was conducted via telephone interview or online survey via the Research Electronic Data Capture platform (REDCap)[8].

Participants

To be eligible for participation at T1, children were aged ≥ 3.0 and ≤ 5.11 years. To be eligible for participation at T2, data collection at T1 needed to have occurred within the preceding 12-months.

Variables

Physical activity, sedentary time and sleep

Primary caregivers reported their child's total physical activity (TPA), moderate- to vigorous-intensity physical activity (MVPA), total screen time, and the child's bed and wake times and nap duration via questionnaire. Additional questions asked about screen device use before bedtime, screens in bedrooms, and sleep quality. Questions were based on the recommendations for each behaviour guideline (Okely 2017) [10] and then tested and refined as part of the SUNRISE pilot study, ensuring feasibility and acceptability among participating populations. Concurrent validity of the questions asking parents to report time spent in TPA and MVPA was evaluated using T1 data from Actigraph GT3X + accelerometers on 436 and 377 participants, respectively. Correlations were significant for TPA (r = 0.14; P = 0.003) and for MVPA (r = 0.16; P = 0.002). Classification rates for meeting or not meeting WHO Guidelines based on Actigraph and parent-reported data were calculated. The sensitivity and specificity were 53% and 61% for TPA and 60% and 46% for MVPA, respectively.

Demographics and COVID-19 factors

Child age and sex and their parents highest level of education were collected. Each country's Human Development Index and World Bank income classification were recorded and the data collection locations in each country were classified as urban or rural (Table S1).

In addition, the T2 survey included questions around the circumstances families faced during COVID-19 restrictions. These included parental working arrangements, type of housing, people per household, time spent outdoors, parental stress and exhaustion levels, parental efficacy in supporting their child to maintain healthy movement behaviours, support received from their early ECEC service, and resources accessed in the home. These were adapted from a similar survey[9].

COVID-19 restrictions

Data on six indicators of government responses to the Coronavirus pandemic, deemed relevant to the research questions, were obtained from the Oxford COVID-19 Government Response Tracker (OxCGRT)[10]. Two indicators, *ability to go outside to exercise* and *playground closures* were added. Each country checked if the tracker information was correct for the areas where data were collected at the height of restrictions (Table S2). Three categories of restrictions (low, moderate and high) were developed based on the variables deemed most influential on young children's movement behaviours in this context. These were *ECEC closure* and *ability to go outside*. A low level of restriction was defined as pre-school being open or available to children of essential workers, and the ability to go out in public for exercise. A moderate level of restriction as ECEC being closed and the recommendation to limit time outside, e.g. only within immediate residential area, specific times of day, maintaining physical distancing etc. A high level of restriction was applied to countries where ECECs were closed and people were not allowed to go out in public to exercise.

Measurement

Data collectors received training in how to administer the parent survey and use the REDCap[8] hosted at the University of Wollongong, Australia. Prior to participation, informed consent was obtained from the parents/legal guardians of participating children.

Bias

The results presented are based on the report of the child's primary carer, and as such there is a risk of recall bias. The internal validity of the dataset is strengthened given that for 86% of the sample, the same primary caregiver reported data at both time points. The response rate of 76% at T2 further reduces sample bias.

Study size

Power calculations were performed for meeting TPA and SST guidelines. Due to the sampling methods we accounted for within person and within ECEC service dependence of the outcomes. The intra-class correlations within ECEC services and within children were estimated[11,12] and then converted to random effect variances. For each generated data set, a multi-level model was fitted with random intercepts for ECEC service, children, and the additional random slope β_k for the change in outcomes from T1 to T2 in country k assuming that country effects varied according to the assumption $\beta_k \sim N(\beta, \sigma_\beta^2)$, with β the mean change effect across countries. Finally, the significance of parameter β was tested. The estimated power was ≥80% for meeting both the TPA and SST guidelines. All analyses were conducted using R[13] and R package lmer[14] with optimizer "bobyqa" used to fit the multi-level models. Missing data were ignored and not imputed; that is, missingness was assumed to be at random.

Statistical methods

Descriptive data were calculated as frequencies (%) or means with 95% confidence intervals (CI, using Wald type confidence interval). Results were presented for the effect *B* as average or effect across countries with corresponding 95% CIs or as average mean change across countries with corresponding 95% CIs. Coefficients were based on a multi-level model with ECEC services as random effects (accounting for cluster sampling), children as random effects (accounting for paired data) and country random effects of change from T1 to T2.

A linear mixed model was fitted to the difference of outcomes at T2 relative to T1. Models similar to the multi-level models for the descriptive results were fitted without the child random effects, as there was only one observation per child. For the outcomes of meeting the guidelines at T2, a logistic multi-level regression model was fitted accounting for T1 with ECEC service and country sites as random effects.

Results

Participants

The final analytical sample comprised 948 respondents (children's mean age T1 = 4.4 years, SD = 0.6; T2 = 5.2 years, SD = 0.6). The average response rate for the sample was 76%, and the average time interval between T1 and T2 was 9.6 months (SD = 3.8). Of the children, 49% were female, 39% lived in rural areas, 71% were from LMICs, and 63% of parents had some level of tertiary education (Table S3). Eighty-three percent of children went outside during COVID-19 restrictions, and 59% lived in housing with access to an outside play area (Table S4).

At the height of COVID-19 restrictions, 41% of the participants faced high, 46% moderate, and 13% low levels of restrictions. Fifty-three percent, 59%, and 47% of parents were concerned about their child's level of physical activity, sedentary behaviour and sleep, respectively. Around 80% of parents felt able to support their child to have healthy movement behaviours and had received resources from their child's ECEC service and 62% had accessed online resources to support their child's movement behaviours at home. Around one-third of parents reported that they felt more stressed and exhausted than before COVID-19 (Table S4).

Changes in physical activity, sleep duration, and the proportion meeting all four guidelines were small and not statistically significant (Table 1). However, children spent 55 min/day more in sedentary screen time and the proportion who met the SST guideline dropped from 48–25%. Children went to bed 34 min later and woke up 60 min later than before COVID-19. The mean nap time decreased by 19 min/day. Children spent 81 min and 105 min less time outdoors on weekdays and weekend days, respectively.

Table 1
Changes in young children's movement behaviours and sleep characteristics before (T1) and during COVID-19 (T2)

	N	T1	T2	Mean change (95% CI)†			
				Unadjusted	p-value	Adjusted§	p-value
Time spent in movement behaviours (min/day)							
TPA	852	200.7 (5.0)	217.8 (4.8)	16.5 (-40.0,72.9)	0.540	25.1 (-31.7,81.9)	0.361
MVPA	847	60.6 (2.3)	55.6 (2.4)	-5.7 (-25.0,13.6)	0.528	5.6 (-25.3,14.1)	0.552
SST	942	105.3 (3.6)	162.0 (4.2)	57.0 (43.0,71.0)	**< 0.0001**	54.9 (38.6,71.2)	**< 0.0001**
Total sleep duration - including nap (min)	946	664.7 (2.9)	641.2 (3.2)	-22.8 (-42.4,-3.2)	**0.026**	-9.2 (-28.9,10.6)	0.341
Nap duration (min)	287	111.5 (2.0)	97.4 (2.9)	-16.6 (-31.6,-1.6)	**0.034**	-18.5 (-33.6,-3.4)	**0.020**
Proportion of children meeting the recommendations of WHO Global guidelines (%)							
TPA	852	53.1 (2.0)	60.1 (1.7)	1.45 (0.56,3.72)	0.441	1.48 (0.56,3.87)	0.426
MVPA	847	50.8 (1.8)	48.7 (1.9)	0.82 (0.41,1.65)	0.577	0.83 (0.39,1.76)	0.633
SST	942	48.0 (1.8)	24.9 (1.7)	0.28 (0.17,0.46)	**< 0.0001**	0.31 (0.18,0.55)	**< 0.0001**
Sleep	946	84.2 (1.5)	79.3 (1.6)	0.67 (0.44,1.01)	0.055	0.89 (0.57,1.41)	0.628
All four recommendations	842	13.6 (1.4)	10.5 (1.2)	0.77 (0.40,1.48)	0.430	0.91 (0.44,1.88)	0.791
Sleep characteristics							
Bedtime (24Hr:Min)	947	21:20 (0:02)	22:01 (0:03)	0:40 (0:21,1:00)	**< 0.001**	0:34 (0:14,0:54)	**0.003**
Wake-time (24Hr:Min)	946	7:09 (0:02)	8:09 (0:03)	1:00 (0:37,1:23)	**< 0.0005**	0:59 (0:34,1:23)	**< 0.0005**
Poor sleep quality (%)	924	5.4 (1.0)	6.0 (0.9)	0.50 (0.19,1.29)	0.152	0.57 (0.21,1.54)	0.267
Use screen devices 2 hours before bed (%)	922	72.5 (1.7)	65.0 (2.0)	0.66 (0.37,1.18)	0.165	0.76 (0.42,1.41)	0.388
Time spent outdoors (weekdays) (min/day)	934	180.7 (4.6)	105.7 (3.7)	-75.7 (-141.6,-9.8)	**0.028**	-80.9 (-147.6,-14.1)	**0.021**
Time spent outdoors (weekends) (min/day)	941	213.4 (5.0)	115.6 (4.0)	-98.3 (-160.3,-36.4)	**0.004**	-104.7 (-166.7,-42.6)	**0.003**

TPA total physical activity, *MVPA* moderate-to-vigorous intensity physical activity, *SST* sedentary screen time.

Data are presented as mean (standard error) for continuous variables or percentage (standard error) for categorical variables. Bold value indicates statistically significant effect ($p < 0.05$).

†*Mean change effects are presented in min/day format for continuous variables or odds ratio for categorical variables*

§*Adjusted for age by sex interaction, rurality, change in caregiver relationship to child (person who completed the survey), childcare centre (as random effects), country sites (as random effects), and caregivers' highest level of education.*

Table 2
Linear regression of associations between changes in movement behaviours and selected COVID-19 factors

COVID-19 factors	Changes in time spent in movement behaviours							
	TPA		MVPA		SST		Sleep duration	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Level of restrictions	-	-	-	-	-	-	-	-
High (Ref)	6.3 (-185.1,197.7)	52.9 (-160.0,265.8)	27.7 (-25.2,80.7)	36.9 (-31.4,105.2)	-9.7 (-50.0,30.6)	-4.6 (-60.3,51.1)	-14.6 (-70.1,40.9)	-10.4 (-98.1,77.4)
Low	-17.7 (-193.1,157.7)	10.1 (-137.0,157.2)	4.4 (-43.9,52.7)	6.3 (-40.8,53.3)	-18.0 (-52.8,16.7)	-22.5 (-59.2,14.2)	-4.7 (-52.4,43.0)	-28.2 (-83.6,27.2)
Moderate								
Country income level	-	-	-	-	-	-	-	-
High-income (Ref)	44.1 (-96.0,184.2)	78.1 (-96.7,252.9)	0.7 (-41.9,43.4)	22.6 (-33.2,78.5)	-11.5 (-41.9,18.9)	-10.9 (-54.4,32.6)	21.5 (-17.7,60.6)	21.8 (-48.7,92.3)
Low/middle-income								
Go outside during COVID-19	-	-	-	-	-	-	-	-
No (Ref)	7.1 (-22.6,36.9)	9.3 (-20.9,39.4)	5.5 (-7.2,18.3)	6.0 (-7.2,19.2)	2.0 (-16.1,20.1)	5.8 (-12.9,24.5)	4.1 (-11.6,19.7)	4.1 (-11.6,19.7)
Yes								
Caregiver's concern about child's movement behaviour[§]	-	-	N/A	N/A	**-**	**-**	-	-
No (Ref)	-24.1 (-48.2,0.06)	-23.0 (-47.4,1.4)			**15.7 (1.6,19.7)**	**14.9 (0.2,29.6)**	4.7 (-8.2,17.7)	4.3 (-8.9,17.5)
Yes								
Caregiver's perceived ability to support child to have healthy movement behaviours	-	-	-	-	-	-	-	-
No (Ref)	-7.8 (-36.6,21.0)	-10.2 (-39.0,18.5)	8.6 (-3.9,21.0)	7.4 (-5.2,20.0)	-10.1 (-27.1,6.9)	-4.4 (-21.8,13.1)	5.6 (-9.2,20.4)	5.7 (-9.1,20.4)
Yes								
Presence of outdoor space within house compound	**-**	**-**	-	-	-	-	-	-
No (Ref)	**50.9 (16.5,85.4)**	**54.7 (19.0,90.3)**	**17.1 (2.5,31.8)**	**16.7 (1.0,32.3)**	-15.6 (-33.9,2.8)	-16.9 (-37.6,3.8)	1.6 (-15.6,18.7)	1.0 (-17.0,19.0)
Yes								
Number of adults living within the same household	-	-	-	-	-	-	-	-
Two or less (Ref)	5.3 (-18.1,28.6)	3.9 (-19.4,27.2)	-2.6 (-12.8,7.6)	-3.3 (-13.7,7.1)	1.5 (-15.3,12.3)	-0.8 (-15.2,13.6)	-6.3 (-18.4,5.7)	-9.4 (-21.7,2.9)
More than two								
Number of children living within the same household	-	-	-	-	-	-	-	-
Two or less (Ref)	22.5 (-6.6,51.6)	25.2 (-4.1,54.4)	2.5 (-10.1,15.1)	3.2 (-9.7,16.1)	-2.5 (-19.3,14.2)	0.0 (-17.3,17.3)	-2.6 (-17.2,12.0)	-2.6 (-17.3,12.1)
More than two								
Caregiver's perceived level of stress compared to before COVID-19	-	-	-	-	-	-	-	-
Less/about the same (Ref)	-11.5 (-36.4,13.5)	-1.4 (-29.6,26.8)	-4.9 (-15.7,5.9)	-8.4 (-21.0,4.1)	**15.0 (0.4,29.6)**	8.2 (-8.8,25.3)	-1.7 (-14.5,11.1)	4.0 (-10.5,18.5)
More stressed								

TPA total physical activity, *MVPA* moderate-to-vigorous intensity physical activity, *SST* sedentary screen time.

Data are presented as unstandardized regression coefficients (95% confidence interval); bold value indicates statistically significant effect.

Model 1: Adjusted for age (at T2) by sex interaction, change in age (T2 relative to T1), rurality, change in caregiver relationship to child (person who completed the survey), childcare centre (as random effects), country sites (as random effects), caregivers' highest level of education, and children who reported as sick at T2 (preventing from being active at T2).

Model 2: Included all variables in Model 1 and all COVID-19 factors.

[§]*Separate questions were asked for total physical activity, sitting (including screen time) and sleep, but not for MVPA.*

COVID-19 factors	Changes in time spent in movement behaviours							
	TPA		MVPA		SST		Sleep duration	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Caregiver's perceived level of exhaustion compared to before COVID-19	-	-	-	-	-	-	-	-
Less/about the same (Ref)	-10.6 (-35.2,14.0)	-5.4 (-33.2,22.3)	3.8 (-6.8,14.4)	8.2 (-4.0,20.4)	13.3 (-1.2,27.8)	6.1 (-10.5,22.7)	**-12.8 (-25.4,-0.2)**	-13.3 (-27.4,0.7)
More exhausted								
Receiving any support from childcare centre	-	-	-	-	-	-	**-**	**-**
No (Ref)	-8.2 (-51.5,35.1)	-8.2 (-53.7,37.4)	-2.0 (-20.0,16.0)	-0.1 (-19.4,19.1)	-22.6 (-45.9,0.7)	-21.7 (-47.5,4.1)	**22.3 (1.2,43.4)**	**29.8 (8.1,51.6)**
Yes								
Using any resources to support/facilitate child's movement behaviours at home	-	-	-	-	-	-	-	-
No (Ref)	2.7 (-23.2,28.5)	7.2 (-19.0,33.5)	0.8 (-10.3,11.9)	0.3 (-11.2,11.8)	4.4 (-11.0,19.9)	3.2 (-13.0,19.5)	4.8 (-8.9,18.6)	5.0 (-8.9,18.9)
Yes								

TPA total physical activity, *MVPA* moderate-to-vigorous intensity physical activity, *SST* sedentary screen time.

Data are presented as unstandardized regression coefficients (95% confidence interval); bold value indicates statistically significant effect.

Model 1: Adjusted for age (at T2) by sex interaction, change in age (T2 relative to T1), rurality, change in caregiver relationship to child (person who completed the survey), childcare centre (as random effects), country sites (as random effects), caregivers' highest level of education, and children who reported as sick at T2 (preventing from being active at T2).

Model 2: Included all variables in Model 1 and all COVID-19 factors.

§Separate questions were asked for total physical activity, sitting (including screen time) and sleep, but not for MVPA.

Table 2 reports the associations between selected COVID-19 variables and changes in time spent in movement behaviours. Caregivers who were concerned about their child's movement behaviours reported a greater increase in SST (marginal effects: 49.4 min/day vs 65.1 min/day), compared with caregivers who were not concerned. Children who lived in houses with outdoor spaces had a significantly greater increase in TPA (-21.8 min/day vs 29.1 min/day) and a smaller decrease in MVPA (-19.8 min/day vs -2.6 min/day), compared with those with no outdoor space. Children whose caregivers reported receiving support from their ECEC service during COVID had a smaller decrease in sleep duration (-19.0 min/day vs -41.3 min/day) than those children whose service did not provide support to parents.

Table 3 reports the associations between selected variables and meeting the WHO Global guidelines during COVID-19. Compared with countries with a high level of restrictions, children in countries with a low or moderate level were more likely to meet the MVPA guideline (OR = 3.59, 95%CI 1.39, 9.30); SST guideline (OR = 2.71, 95%CI 1.56, 4.70); and sleep guideline (OR = 6.71, 95%CI 1.77, 25.46). Children from LMICs were more likely to meet the TPA (OR = 12.17, 95%CI 3.03, 49.00), MVPA (OR = 1.96, 95%CI 1.02, 3.77) and SST guidelines (OR = 2.16, 95%CI 1.19,3.94) than children from HICs. Compared with children who were not allowed to go outside, those who were allowed were more likely to meet allfour guidelines (OR = 3.30, 95%CI 1.12, 9.76) and the TPA guideline (OR = 1.70, 95%CI 1.05, 2.75). Compared with caregivers who were not concerned about their child's movement behaviours, children of those who were concerned were less likely to meet the TPA (OR = 0.50, 95%CI 0.34, 0.74) and ST guidelines (OR = 0.68, 95%CI 0.47, 0.96). However, children whose caregivers believed they had the ability to support their child's movement behaviours were more likely to meet the MVPA guidelines compared with those who did not believe this (OR = 1.89,

95%CI 1.17, 3.06). Compared with children who lived in houses with no outdoor play spaces, those in houses with outdoor play spaces were more likely to meet the TPA (OR = 2.41, 95%CI 1.32, 4.41) and MVPA (OR = 2.61, 95%CI 1.56, 4.36) guidelines. Children whose caregivers felt more exhausted at the time of the survey compared with before COVID-19 were less likely to meet the sleep guideline than children whose caregivers felt less or the same level of exhaustion (OR = 0.59, 95%CI 0.37, 0.95).

Table 3
Logistic regression of associations between meeting WHO Global guidelines and selected COVID-19 factors

	TPA guideline		MVPA guideline		SST guideline		Sleep guideline		All guidelines
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1
Level of restrictions	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High (Ref)	0.94	4.29	**4.43**	**3.59**	1.13	1.91	**9.50**	**6.71**	2.11
Low	(0.11,7.83)	(0.74,24.90)	**(1.77,11.12)**	**(1.39,9.30)**	(0.52,2.44)	(0.79,4.60)	**(2.60,34.71)**	**(1.77,25.46)**	(0.98,4.54)
Moderate	0.44	0.50	0.67	0.89	**1.98**	**2.71**	1.18	0.76	0.99
	(0.06,3.01)	(0.15,1.65)	(0.30,1.47)	(0.49,1.62)	**(1.08,3.62)**	**(1.56,4.70)**	(0.48,2.89)	(0.38,1.54)	(0.47,2.07)
Country income level	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High-income (Ref)	3.87	**12.17**	0.67	**1.96**	**1.98**	**2.16**	0.44	1.21	1.30
Low/middle-income	(0.81,18.53)	**(3.03,49.00)**	(0.23,1.94)	**(1.02,3.77)**	**(1.09,3.60)**	**(1.19,3.94)**	(0.15,1.31)	(0.55,2.65)	(0.57,2.97)
Go outside during COVID-19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No (Ref)	**1.75**	**1.70**	**1.70**	1.52	1.20	1.19	1.53	1.51	**4.21**
Yes	**(1.10,2.78)**	**(1.05,2.75)**	**(1.06,2.71)**	(0.95,2.45)	(0.76,1.89)	(0.75,1.89)	(0.93,2.51)	(0.92,2.45)	**(1.46,12.18)**
Caregiver's concern about child's movement behaviour[§]	1.00	1.00	N/A	N/A	1.00	1.00	1.00	1.00	N/A
No (Ref)	**0.49**	**0.50**			**0.60**	**0.68**	1.00	0.97	
Yes	**(0.34,0.72)**	**(0.34,0.74)**			**(0.42,0.86)**	**(0.47,0.96)**	(0.65,1.56)	(0.63,1.50)	
Caregiver's perceived ability to support child to have healthy movement behaviours	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No (Ref)	1.25	1.15	**2.19**	**1.89**	1.15	1.14	0.99	0.87	1.56
Yes	(0.77,2.01)	(0.71,1.86)	**(1.35,3.55)**	**(1.17,3.06)**	(0.74,1.79)	(0.73,1.79)	(0.61,1.59)	(0.54,1.41)	(0.71,3.45)
Presence of outdoor space within house compound	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No (Ref)	**1.88**	**2.41**	**2.61**	**2.61**	1.29	1.14	0.80	0.65	**2.83**
Yes	**(1.07,3.30)**	**(1.32,4.41)**	**(1.55,4.40)**	**(1.56,4.36)**	(0.81,2.06)	(0.70,1.87)	(0.46,1.38)	(0.38,1.11)	**(1.43,5.60)**
Number of adults living within the same household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Two or less (Ref)	**1.64**	**1.55**	0.98	0.97	0.98	0.96	1.04	1.12	0.96
More than two	**(1.12,2.42)**	**(1.04,2.33)**	(0.68,1.39)	(0.67,1.40)	(0.70,1.37)	(0.68,1.36)	(0.70,1.53)	(0.76,1.66)	(0.54,1.70)
Number of children living within the same household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Two or less (Ref)	1.21	1.27	1.01	0.92	0.99	0.85	0.99	1.01	1.42
More than two	(0.74,1.98)	(0.76,2.13)	(0.66,1.56)	(0.59,1.45)	(0.65,1.50)	(0.56,1.31)	(0.62,1.58)	(0.63,1.61)	(0.76,2.63)
Caregiver's perceived level of stress compared to before COVID-19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Less/about the same (Ref)	1.03	1.41	1.04	0.98	**0.65**	0.90	0.86	1.06	**0.50**
More stressed	(0.69,1.53)	(0.87,2.28)	(0.71,1.52)	(0.63,1.54)	**(0.45,0.93)**	(0.59,1.37)	(0.56,1.33)	(0.65,1.73)	**(0.26,0.93)**

	TPA guideline		MVPA guideline		SST guideline		Sleep guideline		All guidelines
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1
Caregiver's perceived level of exhaustion compared to before COVID-19	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Less/about the same (Ref)	0.73	0.65	1.18	1.17	**0.63**	0.74	**0.62**	**0.59**	0.71
More exhausted	(0.50,1.06)	(0.41,1.02)	(0.82,1.70)	(0.75,1.83)	**(0.43,0.90)**	(0.49,1.13)	**(0.41,0.94)**	**(0.37,0.95)**	(0.39,1.30)
Receiving any supports from childcare centre	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No (Ref)	1.23	1.33	1.55	1.64	1.16	1.18	1.82	1.64	1.76
Yes	(0.63,2.39)	(0.67,2.64)	(0.85,2.85)	(0.88,3.09)	(0.66,2.05)	(0.64,2.16)	(0.96,3.46)	(0.87,3.09)	(0.66,4.70)
Using any resources to support/facilitate child's movement behaviours at home	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
No (Ref)	1.12	1.16	1.39	1.40	0.89	0.99	1.11	1.05	0.98
Yes	(0.77,1.64)	(0.78,1.72)	(0.93,2.08)	(0.93,2.12)	(0.61,1.28)	(0.68,1.43)	(0.67,1.82)	(0.65,1.71)	(0.54,1.77)

TPA total physical activity, *MVPA* moderate-to-vigorous intensity physical activity, *SST* sedentary screen time.

Data are presented as odds ratios (95% confidence interval); bold value indicates statistically significant effect.

Model 1: Adjusted for age (at T2) by sex interaction, rurality, childcare centre (as random effects), country sites (as random effects), caregivers' highest level of education, children who reported as sick at T2 (preventing from being active at T2), and corresponding T1 measures (e.g., meeting/not meeting TPA guideline at T1 for TPA model).

Model 2: Similar to Model 1 but also included other COVID-19 factors.

[§]Separate questions were asked for total physical activity, sitting (including screen time) and sleep, but not for MVPA.

Discussion

Key results summary

We hypothesised that, compared with pre-COVID-19, there would be increases in SST, decreases in PA and changes in sleep patterns among young children at the height of COVID-19 restrictions. These hypotheses were confirmed except for PA levels. Family and community factors that were associated with changes in movement behaviours included the presence of an outdoor space to play within the home compound, a supportive ECEC service, and parental stress and exhaustion levels. Additional factors that were associated with a greater likelihood of meeting WHO Global guidelines during COVID-19 included living in a LMIC, living in a country with lower levels of restrictions, being able to go outside, having more than two adults living in the house, and having parents who were less concerned about their child's movement behaviours.

The small changes in PA were surprising and contrary to findings that have reported large declines in PA during the pandemic period among older children[9,15,16]. These differences may be explained methodologically. Our study used a longitudinal design with parents reporting their children's current activity levels at a particular point in time while the others were cross-sectional where parents retrospectively reported what changes may have occurred from pre-COVID to during COVID-19, often in the form of Likert scale (more or less active than before), without parents having to quantify the changes. Data reported this way has a greater chance of emotional bias (parents more likely to see things negatively compared with before), especially given the higher level of parent stress and exhaustion during COVID-19. These smaller changes can be explained by more parents being at home during COVID-19 and spending more time with their child, and children getting more time to play due to closure of ECEC services. As children in our study were not attending ECEC and not participating in any structured learning activities they had more time for active play and in home environments that were more conducive to promoting activity than the environments in ECEC services.

The significant increase in SST during the COVID-19 period is consistent with other studies among children[9,15–17]. This is largely due to children spending less time outdoors and in some countries undertaking activities online while at home. Other factors might include parents working from home and using electronic media devices to keep their child busy while they worked. A concern here is that only half the children met the screen time guidelines before COVID-19. This proportion almost halved during COVID-19. Most of this screen time will be sedentary. Although not all SST is detrimental, one must be cautious about the potential consequences of this finding.

There was no change in total sleep duration, unlike among school-aged children and youth who reportedly slept more during the restriction[9]. Reasons for the observed changes in sleep patterns may include children choosing not to nap at home, unlike when attending ECEC where they are required to nap or rest quietly. Parents reported that children slept for longer in the morning, were less tired in the afternoon and therefore they did not nap. There was probably more flexibility around bedtime, with parents allowing their child to go to bed slightly later. These patterns are consistent with what is observed during holiday periods and on weekends[18].

Children spent less time outdoors on weekdays and weekend days during the pandemic. This is consistent with other studies of children and youth during the pandemic[9,15]. Time spent outdoors provides many benefits for children and their parents including higher levels of PA[19]; indeed, in those countries where children were able to play outdoors, higher levels of PA were reported. Policies that allow children to play outdoors while at the same time minimising the risk of transmission of infection are needed. Wearing masks and enforcing physical distancing in playgrounds, parks and other green spaces may provide a solution to this challenge.

Our results highlight the important role parents play in supporting their child to participate in healthy levels of movement behaviours. Parents who were more concerned about their children's movement behaviours were less likely to meet SST or PA guidelines, perhaps because they were aware that these behaviours were being compromised because of COVID-19 and were concerned by this. Their concern may have been perpetuated if parents were spending more time at home with their children than usual. However, children whose caregivers believed they had the ability to support their child were more likely to meet the MVPA guidelines compared with those who did not believe this. It is plausible that these parents were already actively encouraging their children to increase movement, thus reporting a significant amount of time spent in MVPA[9,20]. This distinction between the influence of parents' reported concern (their belief), versus their ability to support their child's movement behaviours (their behaviour), raises questions regarding how best to support parents to encourage children's movement behaviours during times of increased stress and exhaustion such as during COVID-19. This association between parent concern and children's movement behaviours is encouraging because it shows that parents are aware of the importance of healthy levels of these behaviours at this age and of the need to support their child in meeting guidelines.

One-third of parents reported feeling more stressed and exhausted during COVID-19, compared with the period prior to the pandemic. High levels of parental stress and exhaustion were related to poorer movement behaviour outcomes. This is not surprising with ECEC services closed in many countries and parents juggling working from home and educating their children during this period. An association between the struggle to handle childcare responsibilities during COVID-19 and heightened levels of stress and exhaustion within the home environment[21]. Combined with not being able to go outside as normal or children not able to play with their friends creates a "perfect storm" for higher levels of parental stress and exhaustion. It is possible that parent exhaustion, and children's change in sleep, could be attributed to any number of heightened stressors during the pandemic, with family downtime and typical routines thrown out of balance. For instance, engagement with social media and other communication technologies during the pandemic may result in undue stress and anxiety for both parents and children, with potential lasting impacts on daily routines[17]. Parental mental health needs to be considered whendeciding what level of restrictions to impose to control the spread of COVID-19 and the consequences such restrictions may have on other aspects of health. In those countries where levels of restrictions were low, parents' stress and exhaustion was not as high, reaffirming that such restrictions impact parents which may subsequently impact child. Policymakers need to consider this in future pandemics or subsequent waves of COVID-19 when making decisions about whether to close ECEC services or adopt strict home quarantine orders.

Children in LMICs were more likely to meet movement behaviour guidelines then those in HICs. All countries with high levels of restrictions were LMICs. Higher levels of restriction were associated with lower movement behaviours, but living in an LMIC was associated with a higher likelihood of meeting PA and SST guidelines. Children in some LMICs left the cities to spend time with relatives in rural areas, particularly during school holidays, where they had more access to outdoor spaces and enforcement of COVID restrictions were not as strict. With less restriction on their ability to go outside, these children were likely to be adequately active and less engaged in screen time.

Compared with children living in countries with high levels of restrictions, those in countries with low or moderate restrictions were more likely to meet the guidelines for all three movement behaviours. This highlights the interrelationships among the movement behaviours and the impact that restrictions can have across the entire day. If children are not able to go outside this reduces opportunities they have for PA. As a result, children are more likely to be engaged in SST. Lower levels of PA and higher levels of SST in these children results in shorter total sleep durations. The strength of these associations with all three movement behaviours highlights that priority must be given to keeping ECEC services open and providing opportunities for children to go outside. Being allowed outside was also independently associated with meeting all of the guidelines. Children who meet all guidelines at this age are more likely to have better health[4] reinforcing the importance of promoting outdoor play for children during the current pandemic with appropriate risk mitigation strategies.

Generalisability

We found that there were no differences in the proportion of children who met all four movement behaviour guidelines. Of the individual guidelines, only SST increased during the pandemic. This suggests that despite the great economic and socio-cultural variability between the 14 participating countries, the influence of the COVID-19 related restrictions was relatively consistent. As convenience sampling was used, these results are not generalisable beyond the study participants.

Limitations

A limitation of the study was that movement behaviours were captured via parent report and not objectively measured. Whilst there is 72-hour accelerometry data for Time 1, it was not possible to collect this during the height of the pandemic. There is a possibility that parents may have under-reported children's PA levels before COVID-19, as they may not have been aware of the extent of their child's PA in the ECEC setting as well as due to limited time spent with their children. There may also be some degree of social desirability bias in the parent reporting of their child's movement behaviours before and during COVID.

While the overall sample size was close to 1000, it was small in a number of countries and the children who participated are not necessarily representative of a broader population.

Conclusion

This study is unique as it reports on longitudinal changes in movement behaviour in a diverse, international population of young children from urban and rural locations, and the influence of movement restriction imposed by governments in response to the COVID-19 pandemic. Eight of the countries and 71% of participants are low- or middle-income; we know very little about movement behaviours or the impact of COVID-19 in these countries. This study presents a magnitude of changes in movement behaviours, adding to existing findings reporting parents' perceptions of changes in movement behaviours during the pandemic.

The results highlight that factors, which influence healthy levels of movement behaviours, differ between HICs and LMICs and consequently the implications vary. Policies and efforts therefore need to be specific to each country's context with particular attention given to LMICs, which may not have the resources to deal with the challenges faced by caregivers of young children. Children in disadvantaged communities who do not have access to an outdoor space could be particularly affected as these areas become critically important during periods when restrictions are enforced. These findings can inform efforts to support caregivers of young children to promote a healthy balanced pattern of movement behaviours during the COVID-19 outbreak, the recovery phase and future pandemics. Parents' stress and exhaustion levels and their self-efficacy to support healthy movement behaviour patterns in their children need to be addressed, and preventive programs to help with this can be particularly beneficial for parents.

Declarations

Ethics approval and consent to participate

The research was performed in accordance with the Declaration of Helsinki. Overall research approval for the study was obtained from the Human Research Ethics Committee (Ref: 2018/044) from the University of Wollongong, Australia. Each wave of data collection was approved by the relevant Human Research Ethics Committees in each participating country.

Consent for publication

Informed consent for publication has been obtained from all participants.

Availability of data and materials

The dataset analysed during this study is not publically available as we do not have ethical clearance to share this data.

Competing interests

The authors have no financial or non-financial competing interests to declare.

Funding

This study was supported by a NHMRC Investigator Grant awarded to the first author.

Authors' contributions

Anthony D Okely is responsible for the overall content as guarantor.

Anthony D Okely, Katharina E Kariippanon, Ellie K Taylor contributed to the literature search, study design, data analysis, data interpretation, writing and review of the manuscript.

Guan Hongyan, Thomas Suesse, Penny Cross, Kar Hau Chong, Rebecca Calleia contributed to the study design, data collection, data analysis, data interpretation, writing and review of the manuscript.

Catherine Draper, contributed to the study design, data interpretation and review of the manuscript.

Adang Suherman, Ali Turnab, Amanda Staiano, Amy Ha Asmaa El Hamdouchi, Aqsa Baig, Bee Koon Poh, Borja Del Pozo Cruz, Christine Delisle Nyström, Denise Koh Choon Lian, E. Kipling Webster, Himangi Lubree, Hoi Sze Cecilia Chan, Hong K. Tang, Issad Baddou, Jesus del Pozo Cruz, Jyh Eiin Wong, Kuston Sultoni, Maria Nacher, Marie Löf, Mingming Cui, Mohammad Sorowar Hossain, Prasad Chathurangana, Shameema Ferdous, Thanh V. Kim, Uddhavi Kand, Wickramasinghe VP and Xiaojuan Wang contributed to data collection, data interpretation and review of the manuscript.

Acknowledgements

We would like to thank all the parents, children, Early Childhood Education Care service staff, and data collectors who participated in this study. We thank the SUNRISE Leadership Group members for their contribution to the conceptualisation and support for the implementation of the SUNRISE pilot study.

We would like to thank the following individuals for their contribution: Chi L.D. Nguyen; Ellinor Nilsson; Imane El Menchawy; Iztiba Mallik Deeba; Jajat; K.A.D Kumari; Johan Ng; M.P.K Gayamini; Maria Henström; Mahmudul Hasan; Mesa Rahmi Stephani; Nhan M. Le; Nur Indri Rahayu; Syifa F. Syihab; Serina Wehbe El

Masri; Risma; Wulandari Putri.

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