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Original Article

Preschool-aged children 24-hour movement behaviours before and during COVID-19

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ABSTRACT

The coronavirus disease 2019 (COVID-19) pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) affected health, economies, and lifestyles, but little is known about its impact on children. We aimed to investigate changes in 24-hour (h) movement behaviours of pre-school children before and during COVID-19, and factors that influenced these. Children aged 3–6 years were recruited in Beijing in 2019, and their movement behaviours over 24 h assessed by questionnaire, as part of the International Study of Movement Behaviors in the Early Years (SUNRISE) study. We conducted the survey again during COVID-19, and compared the children's movement behaviours before and during COVID-19 and associated factors. Overall, 196 parents completed the survey at both time points. The percentage of children meeting movement guidelines decreased during the pandemic ($p < 0.01$). Total physical activity decreased less among children getting good quality sleep or with more adults in the household ($p < 0.01$). Children who were not cared for primarily by their mother had a greater decrease in moderate to vigorous intensity physical activity ($p = 0.02$), but the decrease was smaller among children whose parents used the internet to support their physical activity and/or screen time ($p < 0.05$). Children who used electronic screen devices in the 2 h before bedtime or whose parents reported body temperature in webchats had a greater increase in sedentary screen time ($p < 0.05$). Children spending more time outdoors showed a smaller decrease in sleep ($p < 0.01$). Overall, children's movement behaviours changed significantly during the pandemic.

1. Introduction

The early years are a vital period for physical, social and cognitive development, and for establishing healthy behaviour, which may persist into later life.[1,2] Previous research suggests that healthy movement behaviours support normal growth and development as well as physical, psychological and cognitive well-being among preschool-aged children.[3] Three types of movement behaviour—physical activity (PA), sedentary behaviour (SB) and sleep—are possible. The way that these are combined in any 24-hour (h) period is known as 24-h movement behaviours (24-h MBs). How individuals combine these three types of activities throughout the day can have a significant impact on physical and mental health.[4] The importance of these behaviours has been acknowledged in recent guidelines on 24-h MBs in several countries (e.g., South Africa, Australia and Canada).[5–7] In 2019, the World Health Organization (WHO) developed global guidelines for children under 5 years old. These recommend that over every 24-h period, children aged 3–5 years should be physically active for at least 3 h, engage in no more than 1 h of sedentary screen time and have 10–13 h of good-quality sleep.[8] Evidence shows that movement behaviours are associated with adiposity in childhood.[9] Children who are overweight or obese are at greater risk of developing cardiovascular diseases, type 2 diabetes and non-alcoholic fatty liver disease in both childhood[10] and adulthood.[11,12]

The rapid emergence of coronavirus disease 2019 (COVID-19)[13] as an infectious disease caused by the severe acute respiratory syndrome

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Abbreviations

PA	Physical Activity
SB	Sedentary behaviour
24-h MBs	24-h movement behaviours
WHO	World Health Organization
e.g.	exempli gratia
COVID-19	coronavirus disease 2019
SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
TPA	total physical activity
MVPA	moderate-to-vigorous intensity physical activity
SST	sedentary screen time
SUNRISE	The International Study of Movement Behaviors in the Early Years (https://sunrise-study.com/)
REDCap	Research Electronic Data Capture
CI	confidence interval
OR	odds ratios
SD	standard deviation
S.E.	Std. Error
M	mean
Mins	minutes
24-h	24-hour
ST	screen time
TV	television
n	number
t	student's *t*-test
Z	rank sum test
χ^2	chi-square test
p	probability

coronavirus 2 (SARS-CoV-2) virus in 2020 resulted in an unprecedented crisis.[14] COVID-19 caused many people to be hospitalized, and many more to be confined to their homes for long periods. This dramatic change in lifestyle, resulting from immobilization (hospitalization and bed rest), quarantine, and physical inactivity may have had a secondary impact on health and wellbeing among both those infected and the general population.[15] The COVID-19 pandemic caused social and economic disruption, and the closure of schools and kindergartens.[16] It also had a significant impact on individuals' 24-h MBs.[17–21] In China, physical distancing measures and requirements to remain at home resulted in some restrictions on children's movement and physical interactions.[22] This probably resulted in follow-on effects, such as less activity and more sedentary behaviour, with less consistent sleep patterns and more screen time.[23,24]

The primary goal of The International Study of Movement Behaviors in the Early Years (SUNRISE https://sunrise-study.com/) study is to assess the proportion of children adhering to the WHO Global Guidelines in countries with different socioeconomic status.[25] It also aims to determine how 24-h MBs are linked to health indicators in the early years, and identify variations between countries.[26] A SUNRISE pilot study was designed and piloted in China, and first examined 24-h MBs before the COVID-19 pandemic. The pandemic is known to have had significant impacts on individuals' 24-h MBs.[27] Some studies have examined changes in the prevalence of 24-h MBs in children before and during the pandemic,[17–21,23,24] but little is known about the factors associated with integrated 24-h MBs in young children. The aim of this longitudinal study was to compare pre-school children's 24-h MBs before and during the COVID-19 pandemic in China. The study also sought to examine the relationship between COVID-related factors, and changes in preschool children's physical activity, sedentary behaviour and sleep.

2. Material and methods

2.1. Study design

A cluster sample from a kindergarten located in the Shijingshan District of Beijing was recruited in the longitudinal study. Before the COVID-19 pandemic, 251 children and their caregivers were recruited and baseline data were collected about 209 children between September and October 2019 by three Chinese researchers as part of the pilot SUNRISE study (https://sunrise-study.com).[28] Subjective measurements were made of the 209 children's movement behaviours over 24 h, and their primary caregivers and teachers provided information on aspects of the children's physical activity, sedentary screen time and sleep. During the COVID-19 pandemic, all children had to stay at home. Follow-up data on 196 children were collected from their primary caregivers in May–June 2020 (during the pandemic) by telephone interview and online survey through the Research Electronic Data Capture (REDCap).[28–30] We extracted the same content for analysis from both sets of data. Data collectors received training before data collection at both time points. During this phase, some population level interventions, including travel bans and the national emergency response, were in place to flatten the COVID-19 epidemic curve in China.

2.2. Ethical approval

The research was performed in accordance with the Declaration of Helsinki. This study was approved by the Ethics Committee of Capital Institute of Pediatrics under the code NO.SHERLL2020016. Informed consent was obtained from the children's parents or guardians.

2.3. Participants

Before the pandemic, 251 children and their caregivers were recruited in the kindergarten. Caregiver surveys were either self-administered by the children's parents, or, if there were literacy barriers, via interview. In total, 42 participants were excluded, of whom 31 were sick or unable to go to kindergarten, six were under 3 years old, and five were over 6 years old. In the follow up period, 196 children participated during May and June of 2020, and 13 children were lost to the study because their parents refused to participate in the follow-up survey.

To be eligible for participation pre-COVID-19, children had to be aged between 3.0 and 6.0 years, attending pre-school and generally healthy. Considering that children under 3 years old were newly enrolled and might experience separation anxiety, we decided to exclude any of this age, to avoid increasing their anxiety.

Children were ineligible if they were taking medication or had a medical diagnosis of a physical or mental impairment (except for overweight or obesity). Caregivers were required to be the primary caregiver and have a good understanding of the child's daily physical activity and behaviour. Before participation in both surveys, all eligible children's parents/guardians were provided with paper versions of information sheets and consent forms.

2.4. Study instrument

Before the COVID-19 pandemic, we collected children's movement behaviours as baseline data on physical activity, sedentary screen time and sleep duration using the Sunrise questionnaires (Chinese version) (https://sunrise-study.com).[28] The follow-up data were also collected using Sunrise questionnaires (Chinese version) through the Research Electronic Data Capture (REDCap) on children's 24-h MBs. The SUNRISE study took place in 14 countries.[28]

The Chinese version of the SUNRISE questionnaire included demographic data on the child's age and sex, their primary caregivers, and the primary caregiver's age and education. Before the COVID-19

pandemic, the primary caregiver reported on the child's physical activity at home, including total physical activity (TPA), moderate-to vigorous-intensity physical activity (MVPA), and sedentary screen time (SST), and the child's bed- and wake times and nap duration, in hours and minutes (min) per day. Physical activity information at kindergarten was reported by the teacher as additional information to the parent questionnaire. We calculated each child's combined physical activity information from these two sources to give the total time spent in physical activity, screen time, and sleep. The follow-up data on children's 24-h MBs was reported by the child's primary caregiver only, because children did not attend kindergarten during the pandemic.

The national physical activity guidelines for pre-schoolers aged 3–6 years old were used as criteria to define the proportion meeting requirements, which were ≥ 180 min daily of TPA, ≥ 60 min daily of MVPA, and no more than 1 h of SST (e.g. television viewing, using a computer or tablets/smartphones while sitting.[30] Participants were categorized as meeting the sleep guideline if their average sleep duration was between 10 h and 13 h per day.[30,31]

We added some factors associated with the COVID-19 pandemic in 2020.[28] This included questions around the circumstances families faced during the pandemic,[28,32] including primary caregiver role, whether the child was able to play and go outside during the pandemic, whether the family used any resources to support/facilitate the child's movement behaviours at home, whether they received any messages about prevention of COVID-19 from the kindergarten, and whether they reported the child's body temperature in a webchat every day. Other questions included whether parents were concerned about the child's level of physical activity, sitting (including screen time) or sleep, whether they felt able to support the child to have healthy movement behaviours, the number of children and adults living in the household, and the parent's level of stress and exhaustion compared with before the pandemic.

2.5. Statistical analyses

The data were entered into Excel Software 2007. All statistical analyses used STATA 10.0 software (StataCorp LLC,4905 Lakeway Drive, College Station, Texas, USA). Descriptive data were calculated as frequencies (%) or means with 95% confidence intervals (*CI*, using Wald confidence intervals). Categorical variables were presented as frequency and percentages and continuous variables as means with standard deviation (*SD*). Associations were tested using chi-square analyses or the correlation index, depending on the type of variables involved. The statistical level of significance was $p < 0.05$ (two-tailed). The multiple linear regression model considered participants' characteristics and other factors during COVID-19. Relevant outcomes were presented as odds ratios (*OR*) with 95% *CI*.

3. Results

3.1. Participants' characteristics

A total of 196 children were included in the analytical sample. Participating children were aged 3–6 years (mean age = [4.36 ± 0.83] years old), 53.57% were boys and 46.43% were girls. The primary caregivers were mothers for 153 children (78.06%). The mean maternal age was (35.85 ± 3.76) years, and mean paternal age was (37.16 ± 4.65) years. Overall, 187 (95.41%) primary caregivers' education level was junior college or above (Table 1).

Table 1
Participants' characteristics ($n = 196$).

Study sample		
Maternal age (years), *M* (*SD*)		35.85 (3.76)
Paternal age (years), *M* (*SD*)		37.16 (4.65)
Parent/caregiver's relationship to the child participating in the study, *n* (%)	Mothers	153 (78.06)
	Fathers	36 (18.37)
	Grandparents and others	7 (3.57)
Caregiver's education level, *n* (%)	Senior high school and below	22 (11.28)
	Junior college	48 (24.62)
	College and above	125 (64.10)
Child demographic profile		
Sex, *n* (%)	Boys	105 (53.57)
	Girls	91 (46.43)
Age (years), *M* (*SD*)		4.36 (0.83)
Age groups (years), *n* (%)	3–	74 (37.76)
	4–	75 (38.27)
	5–6	47 (23.98)

Abbreviations: *n* = number; *M* = mean; *SD* = standard deviation.

3.2. Children's 24-h changes in movement behaviours before and during the COVID-19 pandemic

Table 2 and Fig. 1 show participants' 24-h MBs before and during the COVID-19 pandemic. TPA decreased ($p < 0.01$), and the percentage meeting the TPA guideline also decreased (from 84.69% to 47.45%, $p < 0.01$). MVPA and the percentage meeting the MVPA guideline decreased from 35.70% to 22.45% (both $p < 0.01$). SST increased and the percentage meeting the sedentary screen time guideline decreased from 85.70% to 47.45% (both $p < 0.01$). Sleep duration decreased but sleep quality increased ($p < 0.01$). The proportion of pre-schoolers who met the sleep guideline decreased from 90.81% to 86.73% ($p < 0.01$). The proportion of pre-schoolers who met all four guideline recommendations declined from 29.08% to 6.63% ($p < 0.01$). Children went to bed 42 min later ($p < 0.01$) and woke up 48 min later ($p < 0.01$) than before COVID-19. The proportion of pre-schoolers who used screen devices in the 2 h before bedtime increased from 47.45% to 51.53%, but the difference was not statistically significant. Similarly, time spent outdoors sharply decreased on weekdays and at weekends (both $p < 0.01$).

The stepwise linear regression models were established by controlling child sex and age and the primary caregiver's educational level as covariates. The results of examining the association between changes in 24-h movement behaviours and selected COVID-19 factors are shown in Table 3. The child having good quality sleep and the number of adults in the family were positively associated with TPA changes ($\beta = 28.84$, 95% $CI = 9.52$–48.16; $\beta = 25.48$, 95% $CI = 6.73, 44.24$). Children whose primary caregiver was their mother were less likely than those primarily cared for by their father or grandparent to show a decline in MVPA during the COVID-19 pandemic ($\beta = -9.67$, 95% $CI = -17.79, -1.56$). Using the internet to support the child's physical activity and/or screen time at home was positively associated with MVPA changes ($\beta = 20.72$, 95% $CI = 3.68, 37.77$). Use of electronic screen devices in the 2 h before bedtime during the pandemic was positively associated with SST changes ($\beta = 27.54$, 95% $CI = 14.00, 47.32$). Reporting body temperature in a webchat every day during COVID-19 was positively associated with SST changes ($\beta = 21.77$, 95% $CI = 6.08, 42.18$). Lastly, playing or going outside during COVID-19 was positively correlated with sleep duration changes ($\beta = 39.17$, 95% $CI = 5.27, 67.56$).

4. Discussion

Our findings confirmed our hypothesis that COVID-19 had a negative impact on preschool children's 24-h movement behaviours in China. In

Table 2
Changes in children's movement behaviours and sleep characteristics before and during COVID-19.

	n	Pre-COVID-19	During COVID-19	$t/z/\chi^2$	*p*
Time spent in movement behaviours(min/day)					
TPA (min; *M* [*SD*])	196	241.1 (65.17)	178.44 (104.33)	−7.62	< 0.01[a]
MVPA (min; *M* [*SD*])	196	47.04 (22.94)	26.20 (31.72)	8.30	< 0.01[a]
Sedentary screen time (min; *M* [*SD*])	196	49.07 (43.80)	97.42 (65.41)	−8.53	< 0.01[a]
Sleep duration (min; *M* [*SD*])	196	710.31 (53.48)	639.18 (57.86)	14.06	< 0.01[a]
Proportion of children meeting the recommendations of WHO Global guidelines					
Meeting TPA Guideline (%)	196	84.69	47.45	60.64[b]	< 0.01[a]
Meeting MVPA Guideline (%)	196	35.70	22.45	8.36[b]	< 0.01[a]
Meeting Screen Time Guideline (%)	196	85.70	47.45	64.49[b]	< 0.01[a]
Meeting Sleep Guideline (%)	196	90.81	86.73	19.70[b]	0.21
Meeting all four recommendations (%)	196	29.08	6.63	29.15[b]	< 0.01[a]
Sleep characteristics					
Bedtime (24 h:min) (*M* [*SD*])	196	21:12 (0:43)	21:54 (0:42)	2.87	< 0.01[a]
Wake-time (24 h:min) (*M* [*SD*])	196	7:08 (0:32)	7:56 (0:48)	10.39	< 0.01[a]
Sleep quality (*M* [*SD*], Score 1 to 7)	196	5.63 (1.18)	6.14 (0.86)	6.33	< 0.01[a]
Use of screen devices 2 h before bed (%)	196	47.45	51.53	0.65[b]	0.42
Outdoor time(min/day)					
Time spent outdoors (weekdays) (min) (*M* [*SD*])	196	108.37 (43.95)	41.43 (74.66)	11.88	< 0.01[a]
Time spent outdoors (weekends) (min) (*M* [*SD*])	196	241.84 (81.73)	52.65 (89.08)	21.15	< 0.01[a]

Abbreviations: COVID-19 = coronavirus disease 2019, *n* = number, *t* = Student's *t*-test, *Z* = rank sum test, χ^2 = chi-square test, *p* = probability, min = minutes, *M* = mean, *SD* = standard deviation, WHO = World Health Organization, TPA = total physical activity, MVPA = moderate-to-vigorous intensity physical activity, ST = screen time, PA = physical activity.
*$p < 0.05$.
[a] $p < 0.01$.
[b] Chi-squared test.

our study, compared with pre-COVID-19, children's physical activity levels and MVPA declined, their sedentary screen time significantly increased, sleep duration decreased but sleep quality increased ($p < 0.01$). These results are consistent with previous studies among older children in Chile.[33] The proportion meeting all four recommendations (≥ 180 min daily for TPA, ≥ 60 min daily for MVPA, no more than 1 h for SST, average sleep duration between 10 h and 13 h per day) declined from 29.08% to 6.63%, and the time spent outdoors decreased for both weekdays and weekends ($p < 0.01$). This is a significant and concerning change, reflecting important secondary detrimental effects from this pandemic. Our findings are consistent with previous studies.[24] Children who meet all guidelines are more likely to have better health outcomes,[31] reinforcing the importance of active play for children during the pandemic. We also hypothesized that our findings may inform efforts to recommend some practical strategies to mitigate the potential damage.

In particular, one notable finding is that TPA and MVPA decreased. The results were consistent with the results of a Spanish study on preschool-aged children.[34] Compared with before the COVID-19 pandemic, our study found small changes in physical activity, unlike studies that have reported large declines in physical activity during the COVID-19 pandemic among older children.[32,35,36] Compared with older children, younger children remained comparatively active during the pandemic. During the pandemic, parents had to stay at home and could therefore accompany and play with younger children, especially because kindergartens were closed. The difference from older children may be because school-age children were required to attend a daily online class each weekday.

We found some factors that were associated with decreasing physical activity. It has been reported that children spent less time outdoors during the pandemic.[32,35] Reduced outdoor playtime may have a substantial impact on reduced MVPA and PA among children. In countries where children were able to play outdoors, there were generally higher levels of physical activity.[30] Outdoor play is associated with higher levels of physical activity and better mental health.[37] We found that living in households containing more adults during COVID-19 was positively associated with TPA changes. The Chinese government implemented strategies such as closed borders and social distancing to minimize the spread of COVID-19 and protect citizens.[13] Many children had not been away from their friends for so long before. This probably had a substantial impact on the daily movement behaviours of young children. Children whose primary caregiver was their mother were less likely than those cared for by their father or grandparent to show a decline in MVPA

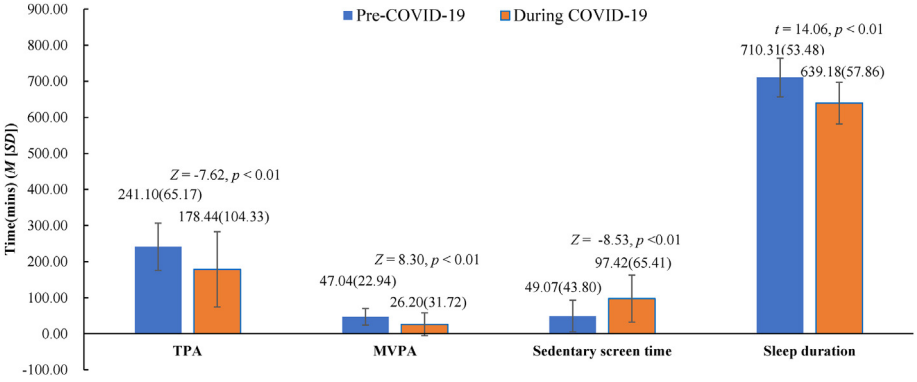

Fig. 1. Children's 24-h MBs before and during the COVID-19 pandemic
Abbreviations: TPA = total physical activity; MVPA = moderate-to-vigorous intensity physical activity; mins = minutes; COVID-19 = Coronavirus disease 2019; 24-h MBs = 24-h movement behaviours; *p* = probability; *t* = student's *t*-test; *M* = mean; *SD* = standard deviation; *Z* = rank sum test.

Table 3
Multiple linear regression of associations between changes of children's 24-h movement behaviours and some factors.

Changes in time spent in movement behaviours	*β*	*SE*	*t*	95%*CI*	*p*
△TPA changes					
1. Child's sex	−6.81	10.00	−-0.68	−26.54,12.92	0.497
2. Child's age	5.71	16.55	0.34	−26.93,38.34	0.731
3. Caregiver's educational level	−16.78	12.12	−1.39	−40.69, 7.12	0.168
4. The quality of child's sleep	28.84	9.79	2.94	9.52, 48.16	0.004[b]
5. The number of adults	25.48	9.51	2.68	6.73, 44.24	0.008[b]
△MVPA changes					
1. Child's sex	6.20	3.35	1.85	−0.41, 12.82	0.066
2. Child's age	5.63	5.47	1.03	−5.17, 16.43	0.305
3. Caregiver's educational level	−0.85	4.26	−0.20	−9.25, 7.55	0.843
4. Primary caregiver role in family	−9.67	4.11	−2.35	−17.79, −1.56	0.020[a]
5. Use internet to support your child's physical activity and/or screen time at home	20.72	8.64	2.40	3.68, 37.77	0.017[a]
△SST changes					
1. Child's sex	9.01	5.51	1.63	−0.31, 21.47	0.104
2. Child's age	1.93	8.44	0.23	−16.92, 16.40	0.819
3. Caregiver's educational level	−2.63	6.13	−0.43	−13.39,10.73	0.668
4. Use screen devices 2 h before bedtime	27.54	8.37	3.29	14.00, 47.32	0.001[b]
5. Report body temperature in webchat every day	21.77	9.15	2.38	6.08, 42.18	0.018[a]
△Sleep duration changes					
1.Child's sex	−4.82	6.31	−0.76	−25.90, 13.35	0.447
2.Child's age	−11.02	9.93	−1.11	−21.82, 4.23	0.269
3.Caregiver's educational level	−13.06	7.21	−1.81	−14.82, 26.70	0.072
4. Play/go outside during COVID-19	39.17	13.11	2.99	5.27, 67.56	0.003[a]

Abbreviations: *SE* = standard error, *CI* = confidence interval, *t* = Student's *t*-test, χ^2 = chi-square test, *p* = probability, TPA = total physical activity, MVPA = moderate-to vigorous-intensity physical activity, SST = sedentary screen time, PA = physical activity, ST = screen time, 24-h = 24-hour, COVID-19 = coronavirus disease 2019, TV = television.

Dependent variables.

△TPA changes, the difference in TPA before and during COVID-19, quantitative.

△MVPA changes, the difference in MVPA before and during COVID-19, quantitative.

△Sedentary screen time changes, the difference in screen time before and during COVID-19, quantitative.

△Sleep duration changes, the difference in sleep duration before and during COVID-19, quantitative.

Variables included in the linear regression analysis.

Covariates.

Child's age (3.00–6.04 years old, quantitative); Child's sex (1 = boy, 2 = girl, qualitative).

Primary caregiver's education (1 = Senior high school and below, 2 = Junior college, 3 = College and above, qualitative).

Independent variables.

1. The quality of child's sleep (Levels 1–7, quantitative; 1 indicates very difficult to settle, wakes many times during the night for prolonged periods and is very restless (tosses and turns, throw off bedclothes) and 7 indicates settles and drifts off to sleep within a few minutes, sleeps right through the night soundly and deeply).
2. Primary caregiver role in family (1 = mother, 2 = father, 3 = grandparent and others, qualitative).
3. Use internet to support your child's physical activity and/or screen time at home (0 = no, 1 = yes, qualitative).
4. Report body temperature in webchat every day (0 = no, 1 = yes, qualitative).
5. Play/go outside during COVID-19 (0 = no, 1 = yes, qualitative).
6. How many adults (under 18 years old) were living in this household during COVID-19 restrictions? (1 = 1 adult, 2 = 2 adults, 3 = 3 adults, 4 = 4 adults, 5 = 5 adults, quantitative).

No significant changes were observed in other variables.

1. During COVID-19 restrictions, have you been concerned about the level of physical activity, sitting (including screen time) or sleep of your.
child? (1) Physical activity (0 = no, 1 = yes, qualitative); (2) Sitting, including screen time (0 = no, 1 = yes, qualitative); (3) Sleep (0 = no, 1 = yes, qualitative).
2. Do you feel able to support your child to have healthy movement behaviours? (0 = no, 1 = yes, qualitative).
3. How many children (under 18 years old) were living in this household during COVID-19 restrictions? (1 = 1 child, 2 = 2 children, 3 = 3 children, 4 = 4 children, quantitative).
4. During a typical week under COVID-19 restrictions, how stressed did you feel compared with before the restrictions? (1 = less stressed, 2 = about the same, 3 = more stressed, qualitative).
5. During a typical week under COVID-19 restrictions, how exhausted did you feel compared with before the restrictions? (1 = less exhausted, 2 = about the same, 3 = more exhausted, qualitative).
6. Did you get a message on prevention of COVID-19 from the kindergarten? (0 = no, 1 = yes, qualitative).
7. Does your child have electronic screen devices in the bedroom? (0 = no, 1 = yes, qualitative).
8. Do you use TV to support your child's physical activity and/or screen time at home? (0 = no, 1 = yes, qualitative).
9. Do you use smart phone/iPad/similar device or apps to support your child's physical activity and/or screen time? (0 = no, 1 = yes, qualitative).
10. Does your child use screen devices in the 2 h before bedtime? (0 = no, 1 = yes, qualitative).

[a] $p < 0.05$.
[b] $p < 0.01$.

during the COVID-19 pandemic. There is no question that the main caregivers in a family play a key role in facilitating movement behaviours of pre-schoolers.

Compared with pre-COVID-19, there was a significant increase in sedentary screen time during the pandemic. This is consistent with other studies among children.[36,38,39] This can be ascribed to children undertaking activities online while at home. Our study found that screen time varied significantly before and during the COVID-19 pandemic among children who used electronic screen devices in the 2 h before bedtime or whose parents reported their body temperature in a webchat everyday during COVID-19. Factors here might include parents working from home and using electronic screen devices to keep their child busy

while they did so. It is important to be cautious about the potential long-term consequences of increased screen time. It is common to see young children playing with a mobile phone or a tablet. However, the decision about the availability of an electronic device and how and when to use it depends on adults. The concern is that the increase in this practice happens at the expense of activities and social interaction, as well as the impact on other aspects of children's health (overweight and sleep disturbance).[34]

There was no significant change in the percentage of children meeting the total sleep guideline, but there were changes in sleep patterns, duration and quality in our study. Sleep is a key element for the proper health and development of children. We found that sleep quality increased and sleep duration declined during the pandemic. Previous studies reported that most pre-schoolers met the sleep guideline (compliance proportion ranging from 83.1% to 94.0%).[40–44] Physical activity is considered important in improving sleep quality in adolescents and adults.[39,45] The quality of children's sleep in our study was positively related to TPA changes. An improvement in the sleep quality occurs with an increase in the activity time, and so even MVPA has a positive effect.[46] We also found that children playing or going outside were more likely to show smaller changes in sleep duration during the pandemic. Children went to bed 30 min later and woke up 40 min later during the pandemic. This may be because they were not required to attend kindergarten, and therefore slept for longer in the morning, which meant they were less tired at night. These sleep patterns are consistent with what is observed during holiday periods and weekends.[44]

Children were experiencing changes in their usual daily habits, and it is therefore reasonable to find different PA, SST, sleep patterns and duration. A novel finding from our study is that online play resources were important for MVPA. Using the internet to support the child's physical activity and/or screen time at home was positively associated with MVPA changes. This finding reinforces the need to ensure the availability of resources to enable children at home to play, because this is likely to promote these behaviours even now that the world has returned to normal. In Chile, specific content was developed for promoting physical activity through social media and national TV as a response to the pandemic.[33] This idea may contribute to a more nuanced understanding of the relationship between 24-h MBs and its determinants, ultimately informing interventions and strategies to improve individuals' health and well-being.

These findings may inform efforts to support caregivers of preschool children to promote physical activity and reduce sedentary screen time now that the pandemic is over, and to promote a healthy balanced pattern of movement behaviours during the recovery phase. It may also contribute to related public health policy-making. In response to the Healthy China 2030 Action Plan, some interventions aimed to increase physical activity and fitness, and reduce the levels of obesity and diseases associated with physical inactivity among Chinese children.[47] Campaigns are needed to increase awareness about physical activity and to encourage children to participate in home-based physical activity.[48]

This study had some limitations. It was impossible to collect data using device-based measures on a large sample because of the pandemic restrictions. The very specific local policy context means our results may not be generalisable to other communities. Future studies should focus on reducing inaccuracies and improve on the quality of this study.

5. Conclusion

In our study, the proportion of children who met the physical activity guidelines was lower (35.70% vs. 22.45%), and sedentary screen time was higher (47.45% vs. 85.70%), during the COVID-19 pandemic than before. It may be necessary to take action to encourage healthy movement behaviours now that the pandemic is officially over. Initiatives to limit screen time, and increase home-based physical activity and access to outdoor space to improve healthy movement behaviours may be needed to support this vulnerable population. Our study may also assist in developing future public health interventions in emergencies.

Conflict of interest statement

The authors declare no conflict of interest related to this work.

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Ethical approval statement

The research was performed in accordance with the Declaration of Helsinki. This study was approved by the Ethics Committee of Capital Institute of Pediatrics under the code NO. SHERLL2020016. Informed consent was obtained from children's parents or guardians.

CRediT authorship contribution statement

Mingming Cui: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation. **Xiaojuan Wang:** Data curation. **Zhaoxu Lu:** Data curation. **Anthony D. Okely:** Supervision, Project administration. **Katharina Kariippanon:** Writing – review & editing, Supervision. **Ellie K. Taylor:** Writing – review & editing, Supervision. **Ting Zhang:** Supervision, Funding acquisition. **Hongyan Guan:** Supervision, Project administration, Funding acquisition.

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